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A Task Constraint Framework for the Attentional Focus Effect in Sensorimotor Tasks: A Systematic Review and Meta-Analyses

By

Benjamin Phalavong

A Thesis
Submitted to the Faculty of Graduate Studies
Through **The Faculty of Human Kinetics**
in Partial Fulfillment of the Requirements for
the Degree of **Master of Human Kinetics**
at the University of Windsor

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ABSTRACT

A systematic search of English articles in electronic databases (i.e. PubMed, CINAHL, Proquest Nursing and Allied Health Source, PsychINFO, and SPORTDiscus) was implemented using search terms (i.e. attentional focus, focus of attention, motor learning, motor performance, external foc*, internal foc*, constrained action hypothesis, instructions, movement effects, and body movements).Three separate meta-analyses yielded Hedge's *g*s of adopting an external focus relative to an internal focus in the acquisition of tasks of 0.409 (n = 64; 95% confidence interval [CI], 0.295-0.522), in retention of learning of 0.569 (n = 28; 95% CI, 0.404-0.733), and in transfer of learning of 0.556 (n = 15; 95% CI, 0.233-0.879). Heterogeneity was observed for the acquisition and transfer phases, $I^2 = 59.984$ and 58.815, respectively. Subgroup analyses between discrete and continuous task dimensions revealed heterogeneity only in the acquisition phase, $p = 0.031$. R^2 index for acquisition phase revealed $R^2 < 0.0$.

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GLOSSARY

acquisition phase: Identified as the segment of the experimental phase in which the individual receives the experimental intervention (i.e. attentional focus instructional cues/feedback); where learning of the experimental task/skill occurs; reflects transient learning of the task/skill

attentional focus: The method of focusing ones attention, or concentration on particular instructional or feedback cues

external focus: Directing ones' attention to 'technique-related' movement effects during motor task execution

internal focus: Directing ones' attention to body-related aspects of movement during motor task execution

overall summary effect: Used to describe the weighted mean effect size of all the studies included within a meta-analysis

the PICOS approach: An acronym referring to the structured approach of formulating relevant and precise research questions that can be addressed from a systematic review; highlights the various components addressed by the research question: population, intervention, comparator group, the outcomes measured, and study design (Liberati et al., 2009).

retention phase: Identified as the segment of the experimental phase in which the preservation of the original learning (i.e. acquisition) of the task/skill occurs; reflects the relatively permanent learning of the task/skill

transfer phase: Identified as the segment of the experimental phase in which the transfer of the original learned (i.e. acquisition) task/skill occurs with a task/skill of high degree of similarity

true effect (τ^2): The effect size underlying the population. In other words, it is the effect size that would be observed if the sample size was infinite (i.e. sample error approaching zero)

CHAPTER 1

INTRODUCTION

1.1 Attention and Motor Performance

The association between attention and motor performance is a familiar discourse among the motor control and learning literature. As an anecdotal statement – providing instructions to performers that encourage attention-demanding, consciously controlled processing has a detrimental effect on performance has long been present (e.g. Bliss-Boder hypothesis – Bliss, 1892). Accordingly, research interest has focused on the effects of attention on performance. One of the aspects of attention, attentional focus, has been investigated initially as associative (i.e. accentuating attention on bodily sensations when performing a movement) or dissociative (i.e. attenuating attention on bodily sensations when performing a movement) (Morgan, 1978; Weinberg, Smith, Jackson & Gould, 1984), and in terms of breadth (i.e. narrow and broad width) (Moran, 1996; Nideffer & Sagel, 1998). Another aspect of attention, directional attention (i.e. internal and external), has arisen over the past two decades as a potential moderator for influencing motor skill performance and learning.

The differences between internal and external attention of foci were first thoroughly examined by Wulf, Höß, & Prinz (1998). In their first experiment, participants were given instructions while attempting to learn slalom-type movements on a ski simulator. In a between-subjects design, both groups were told as a standardization that the objective of the task was to, “move with as large an amplitude as possible” (Wulf et al., 1998, p. 172). Instructions provided to each group differed whereby one was asked to “try to exert force on the outer wheels as long as the platform moved in the respective direction" (i.e. external focus) (Wulf et al., 1998, p. 172), while the second group (i.e. internal focus) was asked to "try to exert force out the outer foot as long as the platform moved in the respective direction" (Wulf et al., 1998, p. 172). The third group was given no additional instructions (i.e. control group). The three groups performed during practice periods of two consecutive days. During acquisition training, the external focus group yielded superior performance (i.e. greater amplitudes of slalom movements) relative to both internal and control groups, $p < .05$. In addition, the internal focus group was less effective than the control group, suggesting that the 'body-related' instructions degraded performance ($p < .05$). To test for effective learning, a retention test was performed on day three, where no attentional focus instructions were given. Again, results revealed that the external focus group produced statistically greater movement amplitudes versus the internal focus of attention and control groups, whereas the former and latter groups did not differ from each other ($p > .05$). In a subsequent experiment, Wulf et al. (1998) required participants to learn how to balance on an apparatus called a stabilometer. Using a similar experimental procedure (except for the exclusion of a control group), directing the participants' attention to keeping the markers on the platform horizontal (i.e. external focus) versus directing their attention to keeping their feet on the platform horizontal (i.e. internal focus) led to superior performance after the two practice days and enhanced learning as measured via retention test. Ultimately, Wulf et al. (1998) revealed that individuals who were given instructional cues prior to movement execution to focus on the effect of their movement (i.e. adopting an external focus of attention) experienced enhanced performance and learning versus those individuals who were given cues to focus on their body movements that produced the effect (i.e. adopting an internal focus of attention).

1.2 Use of Explicit Instructional Cues

As shown by the initial study conducted by Wulf et al. (1998) and in other subsequent attentional focus studies (e.g. see Wulf et al., 2013, for a review), it is critical that instructions be phrased in a manner that induces the effect. These instructional cues differ subtly, enabling the performer to direct their attention to their own movements or to the effects of their movements on a particular aspect of the task. But what does it mean to adopt a focus of attention that regards the ‘effect of their movements’? Since an external focus refers to any instructional cues to focus on aspects outside of the body, Wulf, McNevin, Fuchs, Ritter, & Toole (2000) sought to determine the nature of the external focus and if different variations of instructional cues were more effective relative to each other. In their first experiment, they wanted to determine whether the effect of focusing on the antecedent aspects of the movement (i.e. the trajectory of the ball moving towards the learners) was different than focusing on the movement outcome (i.e. trajectory of the ball moving away from the racket) while hitting tennis balls at a target. The results indicated that the group focusing on the effects of their movements (i.e. movement outcome) experienced greater learning as shown by a greater target score (i.e. accuracy) in the retention period. While both conditions induced an external focus, only the one directly related to the consequences of their action resulted in a learning advantage. This observation was followed in their subsequent experiment investigating whether the external focus on the effect of the movement was associated with direct consequences of the action (i.e. technique), or associated with the ultimate goal of the task. While hitting golf balls at a target, one group was instructed to externally focus their attention on the club (i.e. technique related) while the other group externally focused their attention to the ball trajectory (i.e. outcome related). The results showed that the group focusing on the technique-related effects experienced statistically greater learning. Taken together, Wulf et al. (2000) revealed the beneficial effect of adopting an external focus of attention on both learning and performance that focuses on technique-related movement effects. The idea of technique-related movement effect lends itself to the fact that it is not so much technique that an external focus lends an advantage to; but the idea of not attending to movement actions, the body ‘self-organizes’ in a way that a better technique is used (a detailed explanation is provided below).

1.3 Effect of Attentional Focus on Feedback

As an extension of using the instructional cues paradigm, several studies have utilized explicit feedback information (i.e. to induce the attentional focus effect) (Shea & Wulf, 1999; Wulf, McConnel, Gärtner, & Schwarz, 2002; Wulf, Chiviacowsky, Schiller, & Avila, 2010). More specifically, these studies investigated whether instructions given to the performer prior to task execution in regards to eliciting an attentional focus effect would hold true for feedback information given during task execution. In Shea & Wulf's (1999) study, participants were given feedback in the form of watching a video display of their mirrored movements while performing a balancing task on a stabilometer. Participants were informed that the concurrent feedback they were viewing corresponded to either external or internal focus perspectives. That is, the internal focus group was told the images represented movements of their feet, while the external focus group was told the images represented movements of the stabilometer platform. The results indicated that the external focus group produced statistically greater performance (as measured by Root Mean Square Error of the horizontal position of the platform from 0 degrees) during the retention period than the internal focus group; indicative of a performance advantage. In another study, Wulf et al. (2002) looked at the generalization of attentional focus feedback cues on a complex skill and its effects on expertise. Utilizing two experiments, they sought to determine which type of feedback (i.e. external versus internal) was more effective and how much feedback was appropriate to give. In experiment 1, the investigators presented a set of four internal focus-related feedback comments to one group, while the other group received a set of four external focus-related feedback comments. Presented after every 5^{th} trial, the experimenters issued feedback statements to participants performing a volleyball ‘tennis serve’. Results indicated that the external focus group displayed statistically greater accuracy than the internal focus group irrespective of expertise and subtype of feedback. In experiment 2, external focus feedback yielded statistically greater accuracy than internal focus feedback for experienced soccer players performing lofted soccer passes in both feedback intervals of every third trial and every trial. In fact, Wulf et al. (2010) replicated Wulf et al.’s (2002, experiment 2) methodology using a soccer throw-in task and found similar results in children aged 10-12. Taken collectively, these studies provide evidence that receiving intermittent feedback that is externally focused between trials is just as effective as giving feedback after every trial.

1.4 Mechanism of Action - Constrained Action Hypothesis

To identify a mechanism of action that could explain the effects of attentional focus, Prinz's common-coding theory provided initial insight. Prinz's common-coding theory (Prinz, 1990, 1997) links both action and perception together suggesting that, actions are programmed in recognition of the effects they produce in the environment (Land, Tenenbaum, Ward, & Marquardt, 2013). In other words, perception of an event would activate the associated action with that event and vice versa (Prinz, 1984). Based on this theory, actions are more effective if they are coded, or planned in terms of their movement effects as opposed to their movement patterns (Wulf & Prinz, 2001). Although the different attentional foci conditions fit the mold of the common-coding theory, it is abstract, and thus, lacks empirical evidence to support it. The theory also fails to allude to the differential effects between external and internal attentional foci and its mechanism of action (Wulf, 2013).

To provide an explanation, the constrained action hypothesis (CAH) was proposed (McNevin, Shea, & Wulf, 2003; Wulf, McNevin, & Shea, 2001; Wulf, Shea, & Park, 2001). According to this hypothesis, focusing attention on the movement effects (i.e. external focus) promotes a more automatic type of movement control by using movement control processes that are considered 'unconscious, fast, and reflexive' (Wulf, 2013). In contrast, adopting a focus that refers to the body movements itself (i.e. internal focus) contributes to a more conscious type of movement control, by intervening in the coordination regulation processes of movement control that would self-regulate. This results in a restriction of the motor system functionality (Wulf, 2007). In addition, the automaticity of movement that is promoted upon adoption of an external focus of attention is assumed to be responsible for the performance and learning advantages (McNevin, Weir, & Quinn, 2013).

1.5 Evidence Supporting the Constrained Action Hypothesis

1.5.1 Dual Task Methodology

Initial support for the CAH comes from Wulf et al. (2001) who utilized a dual-task methodology to assess the automaticity of movement under the different attentional foci conditions. Dual-task methodology is used to investigate the effects of secondary task loading on primary task performance. It functions under the assumption of attentional resource limitation (i.e. consciously controlled movements require a higher demand of working memory than automatized movements) suggesting that execution of a secondary task is assumed to interfere with performance on a consciously controlled motor task but not, or to a lesser extent, interfere with performance of an automatized motor task (Abernethy, 1988). In their study, Wulf et al. (2001) had participants who were subjected to either internal or external attentional focus instructions learn a dynamic balance task on a stabilometer (primary task), while concurrently performing a probe reaction task to an auditory tone (secondary task). The results indicated that adopting an external focus of attention was associated with a better balance performance (low amplitude and high frequency movement adjustments associated with automatic control) as well as a faster reaction time to the secondary task (auditory stimuli) than adopting an internal focus of attention. The finding that more attentional resources were available to perform the secondary task of balancing under external focus conditions (based on the faster reaction times to the probe) led to the conclusion that performance was mediated by more automatic control processes. In contrast, performing the primary and secondary task under internal focus conditions appeared to lead to a competition for limited attentional resources. Consequently, performance on both tasks suffered.

1.5.2 Movement Related Measures

Studies that provide additional evidence lending support for the CAH are studies that directly assess movement execution-related measures. These measures give indication of whether movements are consciously or subconsciously (i.e. automatic) controlled. Examples of these measures include: electromyography (EMG), movement fluidity, and movement regularity.

Vance, Wulf, Töllner, McNevin, & Mercer (2004) were the first to investigate the effects of attention foci conditions at a neuromuscular level. Over two experiments, participants were required to flex and extend their forearm to perform a biceps curl, in order to analyze the effect of adopting either an external (i.e. focusing on the movement of the bar) or internal focus (i.e. focusing on the movement of the arm) on integrated electromyogram (iEMG) activity of the biceps brachii and triceps brachii. The results indicated that when the weight lifted was standardized for each participant as a percentage of maximum voluntary contraction (MVC) and remained constant across the attentional focus groups, iEMG activity was statistically lower and movement time was significantly faster with an external focus (i.e. experiment 1); and in experiment 2, when movement time was controlled for via having participants synchronize their movements with a metronome (i.e. constant range of motion), iEMG activity was still lower with the external focus group, $p < .05$. The reduction in iEMG activity during task execution suggested a greater movement economy in the external focus group, allowing the performer to recruit only the number of motor units that are needed to complete the task.

Several other studies have confirmed this assumption as each of the internal focus groups/conditions led to statistically higher EMG activity levels than adopting an external focus in each of their respective tasks (e.g. Zachry, Wulf, Mercer, & Bezodis, 2005; Lohse, Sherwood, & Healy, 2010; Wulf, Dufek, Lozano, & Pettigrew, 2010).

More recently, Kal et al. (2013) sought to assess and quantify the CAH and confirm the processes occurring upon adopting an external focus during task execution. This was accomplished by utilizing two previous methods to measure automaticity of movement (i.e. dual-task methodology and EMG activity) along with two other measures of automaticity that have not been used in the context of the CAH. These measures included fluency of movement and movement regularity. The fluency of movement is represented during the process of skill acquisition; an individual's movement pattern can be witnessed as transitioning between appearing rigid to a more fluent, smooth movement pattern. In addition, this shift is indicative of a more automatic type of movement control (Hreljac, 2000; Shemmell, Tresilian, Riek, Barry, & Carson, 2005; Thomas, Yan, & Stelmach, 2000). Movement regularity is a measure derived from stochastic dynamics which assesses the sample entropy (i.e. measure of movement disorder/disorganization) (Richman & Moorman, 2000). It has differential interpretations depending on whether the task is discrete (i.e. having a recognizable beginning and end) or continuous (i.e. continuous pattern; not having a recognizable beginning and end) (Schmidt and Lee, 2005). That is, discrete tasks display lower movement regularity when the task is considered automatic, and continuous tasks display higher movement regularity when the task is considered automatic. Utilizing a cyclic one-leg extension-flexion task along with a letter fluency task as the secondary task, the results provide more evidence to support the CAH: cognitive dual tasks costs were statistically higher in the internal focus condition. EMG activity did not differ statistically between attentional focus conditions. However, an external focus led to statistically shorter movement duration, which Kal et al. (2013) interpreted as a more efficient movement pattern. Lastly, the external focus group experienced a more fluent and more regular movement execution than internal focus.

1.5.3 Within-Trial Movement Variability

When plotted on a displacement-time graph, the within-trial movement variability resembles a funnel shape suggesting more variability is present at the initiation or proximal segments of movement, while less variability is present near the point of contact or release (distal segments of the movement) (Bootsma & Wieringen, 1990). This finding is in line with the idea of ‘functional variability’ (e.g. Müller & Loosch, 1999) or ‘compensatory variability’ (e.g. Hossner & Ehrlenspiel, 2010) which proposes that in order to preserve the outcome of a task, the motor system assumes synchronicity of the various degrees of freedoms that are associated with skilled movement on an automatic (i.e. unconscious) level (Wulf et al., 2001). Davids, Button, & Bennett (2008) add another perspective, arguing that this type of movement variability is representative of constant adjustment of the motor system to continuous perturbations of perceptual information residing in an individual’s environment (Land et al., 2013). In other words, the constraints of the task, environment and the individual interact in a cyclic fashion in order for an individual to successfully negotiate (i.e. produce an effect from their movement) with the environment.

The notion that external focus facilitates this phenomenon is possible as Wulf & Prinz (2001) suggested that it enables compensatory variability within numerous movement parameters to ensure that movement is executed properly. Within an attentional focus context, Lohse et al. (2010) measured within-trial movement variability in individuals performing a dart-throwing task and revealed the external focus group yielded greater variability in release angle at the shoulder than at the arm compared to the internal focus group and control. In another study, Land et al. (2013) found reduced within-trial movement variability approaching club head-ball impact during a golf putt in both an external focus group and an irrelevant focus (counting audible tones that occurred during putting) compared with a control group; whose identity resembled an internal focus group based on manipulation checks.

Taken collectively, there is a large evidence based that supports the CAH as the mechanism of action for the attentional focus effect. Previous studies have formally investigated its claim through the utilization of the dual task methodology experimental paradigm; movement related measures such as EMG, movement fluidity, and movement regularity; and within-trial movement variability to assess differences in automaticity of movement between an external and internal attentional focus.

1.6 Attentional Focus Effect Observed in a Variety of Tasks

The attentional focus effect has been investigated in a wide variety of tasks. As a generalization, the tasks can be categorized into the following classifications: movement effectiveness studies, movement efficiency studies, and movement kinematic studies.

1.6.1 Movement Effectiveness Studies

Movement *effectiveness* can be characterized by accuracy, consistency, and reliability of achieving a movement goal (Wulf, 2013). Studies related to movement *effectiveness* and primarily utilize balance as an outcome measure include: balancing on a stabiliometer (Wulf et al., 1998; Shea & Wulf, 1999; Wulf, McNevin, & Shea, 2001; Wulf, Shea, & Park, 2001; Wulf & McNevin, 2003; McNevin, Shea, & Wulf, 2003; Wulf, Weigelt, Poulter, & McNevin, 2003; Chiviacowsky et al., 2010; Jackson & Holmes, 2011), an inflated disk (Wulf, Mercer, McNevin, & Guadagnoli, 2004; Wulf, 2008; Wulf, Landers, Lewthwaite, Töllner, & To, 2009), and a Biodex apparatus to assess posture and balance parameters (de Bruin, Swanenburg, Betschon, & Murer, 2009; Rotem-Lehrer & Laufer, 2007; Laufer, Rotem-Lehrer, Ronen, Khayutin, & Rozenberg, 2007). Studies measuring movement *effectiveness* in terms of accuracy in a wide range of sport-specific or related tasks includes: various golf shots (i.e. pitching, driving) (Wulf & Su, 2007; An, Wulf, & Kim, 2013; Bell & Hardy, 2009) and golf putts (Poolton, Maxwell, Masters, & Raab, 2006, Experiment 1), volleyball serves (Wulf et al., 2002, Experiment 1), soccer kicks (Wulf et al., 2002, Experiment 2) and soccer throw-ins (Wulf, Chiviacowsky, Schiller, & Ávila, 2010), beanbag tosses (Chiviacowsky, Wulf, & Avila, 2012), tennis ball tosses (Saemi, Porter, Ghotbi-Varzaneh, Zarghami, & Maleki, 2012) Frisbee throwing (Ong, Bowcock, & Hodges, 2010), and dart throwing (Marchant, Clough, & Crawshaw, 2007; Marchant, Clough, Crawshaw, & Levy, 2009; Lohse et al., 2010).

1.6.2 Movement Efficiency Studies

Movement *efficiency* can be characterized by the fluency, automaticity and economy of achieving a movement goal (Wulf, 2013). Studies related to movement efficiency primarily utilized muscle activity, maximum force production, speed and endurance as outcome measures. Studies that measured movement efficiency in terms of muscle activity observed decreased muscle activity as measured via Electromyography (EMG) in groups and/or conditions of external focus of attention instruction cues versus groups and/or conditions of internal focus of attention instruction cues or control group (where no instruction cues were given) (Wulf, 2013). Such tasks include: bicep curls (Vance et al., 2004; Marchant et al., 2007), wall-sits (Lohse & Sherwood, 2011), and an isokinetic elbow flexion force production task (Marchant, Greig, & Scott, 2009). Studies that measured movement efficiency in terms of maximum force production witnessed a greater force production with individuals in an external focus of attention group/condition versus an internal focus of attention group/condition and control. Such tasks included: an isometric planter flexion force production task (Lohse, 2012), an isokinetic elbow flexion force production task (Marchant, Grieg, & Scott, 2009), a jump and reach (Wulf, Zachry, Granados, & Dufek, 2007, experiment 2; Wulf & Dufek, 2009; (Wulf, Dufek, et al., 2010), standing long-jump (Porter, Ostrowski, Nolan, & Wu, 2010; Wu, Porter, & Brown, 2012), and discus throwing (Zarghami, Saemi, & Fathi, 2012). Studies that used a measure of speed to define movement efficiency revealed greater speed when adopting an external focus of attention versus internal focus of attention and control group in tasks such as: standing long-jump (Porter, Anton, & Wu, 2012), and an agility ‘L’ run (Porter, Nolan, Ostrowski, & Wulf, 2010). Lastly, studies that measured movement efficiency in terms of endurance witnessed greater endurance in tasks when adopting an external focus of attention. Such tasks include: bench press and free squat weightlifting (Marchant, Greig, Bullough, & Hitchen, 2011), wall-sits (Lohse & Sherwood, 2011) running (Schücker, Hagemann, Strauss, & Völker, 2009), and sit-ups (Neumann & Brown, 2013).

1.6.3 Movement Kinematic Studies

Several studies have investigated changes in *movement kinematics* or whole-body coordination such that whole-body coordination patterns are optimized with an external focus (Wulf, 2013). For instance, a study conducted by Lohse et al., (2010) examined sEMG (surface electromyography) along with motion analysis and performance outcome (accuracy of hitting bull's-eye) of a dart-throwing task. Results replicated previous studies that utilized the similar economy movement measures; namely, that an external focus led to significantly better performance, an increase in movement efficiency, as measured via decreased preparatory time between throws, and reduced EMG activity of the agonist muscle (triceps brachii). More importantly, their kinematic analyses revealed a statistically greater variability in release angle at the shoulder (2.3 degrees) than at the arm (1.9 degrees) when the external focus group was instructed to focus on the flight of the dart. A study conducted by Porter, Nolan, et al. (2010) showed that in a jump-and-reach task joint moments around various joints such as the ankle and knee were correlated with each other when an internal focus to pay attention to the finger was present/adopted. In contrast, the external focus group did not reveal such a correlation. Moreover, Wulf & Dufek (2009) identified the correlated semi-independent body segments as being characteristic to 'freezing' of degrees of freedom that is commonly associated with the beginning stages of skill acquisition, such that it resembles individuals who perform a novel skill. Thus, it could be argued that internal focus could have the effect of constraining the motor system and the external focus could have the effect of liberating the motor system. Lastly, a study conducted by Parr & Button (2009) examined novice learners while practicing a rowing technique known as the ‘catch’, which is defined as the instant the blade makes contact with the water and ‘locks it’. The learners had a six-week training period and received retention and transfer tests seven weeks later. Kinematic analysis revealed that performers who were instructed to focus on the oar blade (e.g. external focus) as opposed to focus on their movements (e.g. internal focus) showed greater improvements in technique (Parr & Button, 2009).

In summary, the empirical evidence amassed throughout the years has overwhelmingly supported an external focus advantage in sensorimotor performance, learning, and transfer over internal focus and/or control groups/conditions where no focus of instructions was given.

CHAPTER 2

CONFLICTING FINDINGS AND POTENTIAL INTERACTIONS

The general consensus within the attentional focus literature suggest learning and performance advantages for an individual who adopts an external focus of attention compared to an internal focus of attention (Wulf, 2013). This concept holds true across the variety of tasks used in previous studies. However, based on the results of a several studies and variations of the magnitude of effect across studies, the external focus advantage currently fails to become universally accepted in the motor control literature. The following section will discuss these studies in detail and provide plausible explanations for the contrary results.

2.1 Null Results

Several studies have reported null effects (i.e. showing no difference between external and internal focus groups) of attentional focus (e.g. Poolton, Maxwell, Masters, & Raab, 2006b; Castaneda & Gray, 2007; Emanuel, Jarus, & Bart, 2008; de Bruin et al., 2009; Lawrence, Gottwald, Hardy, & Khan, 2011; Schorer, Jaitner, Wollny, Fath, & Baker, 2012). Although these studies report effects that contradict the majority of the results in the literature, these results can lend explanations from confounds that exist within them.

In the two experiments conducted by Poolton et al. (2006), they found no differences in mean putting score of novices performing a golf putt (derived from concentric absolute error scores from the centre target) between internal and external focus groups. In addition, Emanuel et al. (2008) found adults that adopted an external focus showed greater accuracy in a dart throwing task versus an internal focus, but could not replicate this finding in children. According to Wulf (2013), methodological concerns shared between these two studies can explain for the null results. More specifically, the sheer amount of information contained in each of the attentional focus instructional/feedback cues may have confound the attentional focus effect by making it difficult for the individual to choose which task-relevant focus to adhere to during execution.

Castaneda & Gray (2007) investigated the effects of attentional focus on batting performance of highly skilled and novice baseball hitters in a baseball batting simulation task and a secondary response task to an auditory tone (making a judgment of movement). The attentional focus conditions consisted of four groups: an 'environmental' focus and external focus (e.g. flight of the ball leaving the bat), an 'environmental' focus and irrelevant focus (e.g. secondary task – responding to an auditory tone), a 'skilled' focus and internal focus (e.g. attending to the movement of their hands), and a 'skilled' focus and external focus (e.g. attending to the movement of the bat). Although Castaneda & Gray (2007) reported statistically higher batting performance in both highly skilled and novice batters who adopted a focus of the flight of the ball (e.g. environmental/external condition); and in the highly skilled batters who adopted the skilled/external focus, the novices showed no significant difference between the latter two conditions. Castaneda & Gray (2007) concluded that the dual task design of the experiment posed an attentional resource overload on the novice performers, such that it may have 'cancelled-out' any existing attentional focus effects.

A study conducted by de Bruin et al. (2009) reported no differences between external and internal focus in dynamic balance parameters and weight shifting scores in older adults who were training a functional balance task over a five week period. While performing the task with their respective attentional focus, they were asked to follow a visual target on a screen in front of them with a cursor that represented their shift in weight. It can be argued that the visual feedback given to the participants obscured the focus of attention instructions (Wulf, 2013). In other words, the effect of visual feedback overpowered and confounded the attentional focus manipulation resulting in a null effect.

The null effects of some studies can also be explained or attributed to the outcome measures utilized. For instance, Lawrence et al. (2011) revealed no differences between attentional focus conditions in performance (as measured by a criteria-check list) of a short gymnastics routine. Based on the results, Lawrence et al. (2011) concluded that the attentional focus effect could not be applied to sports that emphasized form of movement as a performance measure. As reported by Wulf (2013), the Lawrence et al. (2011) study appeared to have several methodological concerns. These include having too many criteria in the scoring system (at least 30 to evaluate movement form), implementing a task that was too demanding for the novice performers, and the focus instructions were irrelevant to the task itself consisting of a lunge, arabesque, full-turn etc. (i.e. external focus: on the movement pathway exerting even pressure on the support surface; internal focus: on exerting an equal force on their feet).

Schorer et al. (2012) investigated the effects of adopting attentional foci on throwing accuracy of novices and experts dart throwers. Although they reported differences between novices and experts in their throwing performance (i.e. radial error from the central target), no clear differences in throwing performance and discrete movement characteristics (i.e. overall movement duration, duration of the flexion and the extension phases of the dart throwing movements) between attentional focus conditions within experts and novices emerged. It can be argued that the discrete movement (i.e. temporal) characteristics that were used as an outcome measure have little merit towards the actual task of dart throwing since it is a self-directed task (i.e. individual can perform at own pace). Thus, the validity of implementing discrete movement characteristics in this study is questioned.

Taken collectively, the studies that report null difference between external and internal focus groups/conditions contain methodological concerns that can explain for these results. As a generalization, they include the amount of information residing within an instructional/feedback cue and the use of visual feedback confounding the attention focus effect, the design of the experiment 'cancelling' of the attentional focus effect, and using an inappropriate outcome measure to measure performance of a task.

2.2 Interaction with Differential Task Dimensions

Throughout the motor control and learning literature, sensorimotor tasks have been classified into multiple dimensions including the discrete/continuous dimension representing movement characteristics of the task and the open/closed dimension representing perceptual characteristics of the task (Schmidt & Lee, 2005).Within the former dimension, discrete tasks are described as having a recognizable start and finish, can occur very rapidly but can require a sizable amount of time for completion, and can be fairly cognitive in nature (Chambaron, Berberian, Delbecque, Ginhac, & Cleeremans, 2009). Such examples of these types of task include: soccer kicks, throwing a baseball, and shooting a free-throw. In contrast, continuous tasks do not have the feature of a recognizable beginning and end as they are defined an arbitrary point in time. In addition, these types of task typically have longer movement times than discrete tasks (Chambaron et al., 2009). Examples of continuous tasks include: balancing, running, and swimming.

The inherent differences between discrete and continuous tasks transcend far past its superficial distinctions. Discrete tasks can invoke greater informational processing in regards to movement control processing. This statement is substantiated by the study conducted by Spencer, Verstynen, Brett, and Ivry (2007). In their study, they utilized functional Magnetic Resonance Imaging (fMRI) to observe cerebellar activity during discrete and continuous rhythmic timed movements. The discrete movement participants produced was characterized by a rhythmic index finger flexion and extension with a brief pause before each flexion; whereas, the continuous task featured a smooth, continuous transition between flexion and extension. The results revealed greater activation in the superior vermis (i.e. a region within the cerebellum affiliated with the timing of events) in discrete movements versus continuous movements. Spencer et al., (2007) also stated that continuous movements do not invoke any involvement with the cerebellum as control parameters (i.e. timing) reside outside the body and can be manipulated through an external variable, such as angular velocity. In addition, there is evidence to suggest differential performance effects based on discrete and continuous tasks. For instance, in Leibovich & Henik's (2013) study, participants performed a discrimination task (i.e. responding to the perceptual stimulus via pressing a key that corresponded to the side of the larger magnitude) and were asked as quickly and accurately as possible to determine which array out of two contained the most dots for the discrete task and which square had a larger area in the continuous task. Results indicated statistical differences in the response time (i.e. reaction time) and the accuracy rates; such that, the continuous task was faster and more accurate in discrimination versus the discrete task.

Within the dimension of representing perceptual characteristics of the task, open tasks are defined by having an unpredictable environment in which the task is performed; whereas closed tasks are defined by having a predictable environment in which the task is performed (Poulton, 1957; Gentile, 2000). Based on this definition, it can be argued that open tasks relative to closed tasks invoke a greater perceptual response because they require prompt adaptations to perturbations occurring in the environment. Examples of open tasks include driving along a busy highway and taking a penalty shot in soccer. Examples of closed tasks include dart throwing and bowling.

As prerequisite to establishing their challenge point framework, Guadagnoli and Lee (2004) provided a useful definition of task difficulty into two distinctions. The first distinction is *functional task difficulty*, referring to how challenging the task is relative to conditions under which the task being performed and the skill level of the individual. For example, a task that features a novice performing a baseball catch on the run would be considered a task with high functional task difficulty. On the contrary, an expert performing a baseball catch while stationary would have low level of functional task difficulty. The second distinction is *nominal task difficulty*, which reflects a constant amount of task difficulty, irrespective of the participants and the conditions under which the task is being performed. This type of task difficulty lends itself from the perceptual and motor performance requirements inherent within the task. In context to the discrete/continuous task dimension and due the level of perceptual-motor requirements, it can be argued that discrete tasks hold a higher level of *nominal task difficulty* compared to continuous tasks. Likewise, in context to open/closed task dimension, due to the unpredictable environmental conditions and relatively higher perceptual requirements, it can be argued that open tasks hold greater levels of both functional and nominal task difficulties.

The notion of differential task difficulty between these two task dimensions holds important ramifications in the context of attentional focus studies. Most studies of the attentional focus effect on task learning and performance have involved novices performing relatively difficult tasks. Wulf, Töllner, & Shea (2007) suggested an inherent difficulty level of the task is necessary in order for the attentional focus effect to emerge. In their two experiments, they asked participants to maintain a steady posture on a force platform of various surfaces (experiment 1: bare platform and foam; experiment 2: inflatable rubber disk) and postures (experiment 1: standing on two legs; experiment 2: standing on both one and two legs) while adopting either an internal, external or control focus of attention. The results indicated a non-statistical effect of attentional focus on balance posture (measured via Root Mean Square Error of centre of pressure vector magnitude) in experiment 1. It was argued that both the tasks were relatively easy for the young adults who performed it (Wulf et al., 2007). However, in experiment 2, a statistically more stable posture arose in the external focus condition versus the internal and control conditions during both one leg and two leg balancing conditions. Taken collectively, the beneficial effects of adopting an external focus of attention may have the potential to increase with task difficulty. However, Wulf et al. (2007) made no distinction of which type of task difficulty as they did not elaborate further on this term. This raises the concern of the attentional focus effect interacting with task difficulty in the nominal and functional dimensions due to differences between task dimensions. In other words, is it possible for the magnitude of the attentional focus effect to change based on whether the performed task is discrete/continuous and open/closed in nature?

In Summary, the above studies highlight a need to systematically quantify the attentional focus effect. This is to formally verify that the null results (i.e. that can explained by confounding variables or ineffective outcome measures) are indeed artifacts of methodological inconsistencies such as confounding the attentional focus effect and utilizing ineffective outcome measures. In addition, there is evidence to suggest differential effects of attentional focus based on the diversity of tasks that differ in terms of varying task dimension classifications. To date, there have been no attempts to address this concern. Thus, a proposition of a theoretical framework aimed at addressing key characteristics of this effect was brought forth. More specifically, the framework is designed to obtain a sense of how the attentional focus effect can vary under the variety of conditions that have been expressed in previous studies.

CHAPTER 3

PROPOSING THE ATTENTIONAL FOCUS EFFECT IN MOTOR PERFORMANCE AND LEARNING: A CONSTRAINTS-LED MODEL

3.1 Developmental Systems Theory

According to Davids, Button, & Bennett (2008), traditional theories of motor skill acquisition generally fall under five approaches: association theories, neuro-maturational theories (e.g. Gesell, 1928; McGraw, 1943), Fitts' (1964) stage theory of motor learning, information-processing theories (e.g. Keele's (1968) Motor Program conceptualization; Schmidt's (1975) Schema Theory, and neuro-computational theories (e.g. Willingham's (1998) Control-Based Learning Theory). In contrast to the traditional theoretical models of understanding movement coordination and control, the Developmental Systems Theory (DST) provides an approach that views the learner as a complex, open, and dynamical biological systems comprised of many independent yet interacting subsystems (Davids et al., 2008). Of these subsystems lies the concept of constraints. Constraints function as a boundary of the coordination and pattern of a movement that is observed (Patterson, 2001). The interacting constraints (i.e. as depicted by the bi-directional arrows) change over time, which can allow for different stable patterns of coordination to emerge from continued experience and exposure of that goal-directed movement (i.e. practice) (Davids et al., 2008). Newell (1984) originally recognized the significance of these constraints that influence skill development later identified three in his theoretical framework: individual, environmental, and task (Newell, 1986). This framework is often conceptualized as a triangle such that the subsystems/constraints can interact interchangeably to contribute to a change in a specific outcome (i.e. attenuate or facilitate movement or performance) during goal-directed behavior (Wattie, Schorer, & Baker, 2015). It is important to note that any change with the constraints can affect a change in a specific outcome (Newell, 1986).

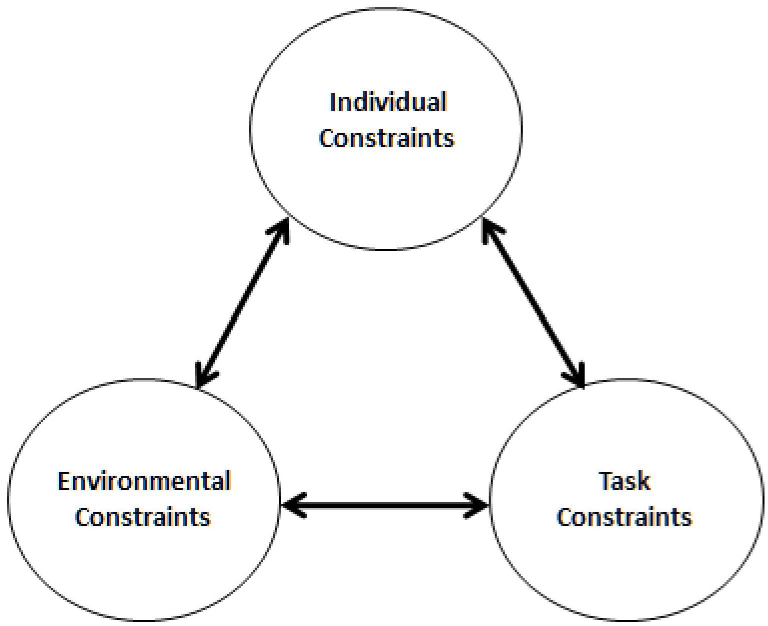

Figure 1. **<u>Newell's (1986) constraints-led model of development of coordination.</u>**

The organismic constraints can be represented by factors that relate to an individual's intrinsic qualities or characteristics. For instance, Newell (1986) coherently described these as tangible measures such as height, weight, age, and sex; or qualitative measures of the individual such as motivation and emotional state. The environmental constraints can be referred to physical features that are external to the individual and can include examples such as ambient lighting, climate, and gravity. Lastly, the task constraints can include specific characteristics such as the objective of the action, rules, spatial boundaries that govern the task (Patterson, 2001).

3.2 Applications of the Developmental Systems Theoretical Framework

The applications of the developmental systems' theoretical framework have been successfully employed with slight modifications to explain and organize the large amount of factors affecting athlete development and talent identification in sport (e.g. Phillips, Davids, Renshaw, & Portus, 2010; Renshaw, Davids, Phillips, & Kerhervé, 2012). More recently, Wattie et al. (2015) applied a modified Newell's (1986) model to heuristically account for possible factors contributing to the relative age effect (RAE). According to Wattie et al. (2015), the RAE ascribes significant advantages and disadvantages through the usage of age cohorts to categorize individuals in the arenas of youth sport and education. Based on a multitude of studies, Wattie et al. (2015) was able to postulate key characteristics that can be attributed to the RAE. These characteristics were structured within Newell's (1986) developmental systems theoretical framework where they were categorized into either three main constraints (e.g. intrinsic, task, environmental). These key-identified characteristics would then be seen as sub-constraints, or a proportion of a particular main constraint. Based on the dynamic nature of many of the key characteristics identified within the three constraints, Wattie et al. (2015) hypothesized using a probabilistic causal component, such that each of the three main constraints adopt the characteristic of a 'causal pie'. The causal pie approach is utilized extensively in the field of epidemiology to model causation and causal inference of various ailments and diseases (e.g. Rothman, 1976). This causal pie can be broken down into each individual pie 'pieces' which represent a single causational component within the broader constraint level. Furthermore, the magnitude of pie pieces can be proportional to 'other pie pieces' within the broader constraint level with the ultimate goal of addressing accountability of that constraint to a particular effect (Wattie et al., 2015).

3.3 Purpose of the Study

It can be argued that a similar approach adopted by Wattie et al., (2015) can be applied to address causation and casual inference of the attentional focus effect. A method to organize and classify the contributing factors of the attentional focus effect in a coherent manner would be to utilize a theoretical model that essentially conceptualizes explained variance of the effect. Although the majority of the attentional focus studies have reported the ubiquitous external focus advantage for motor performance and learning, the mechanisms of this effect are not fully known. Moreover, what is not fully known is if and how the effect could potentially fluctuate under certain conditions or complexities of each study.

Thus, the purpose of this study was to establish a portion of this theoretical framework of the attentional focus effect that can explain for the changes in the magnitude of effect. This theoretical framework is based on Newell’s (1986) constraints-led framework of skill acquisition and development. Due to the variety of tasks used across studies, initial investigation of the task constraint portion of the framework and its interaction with the attentional focus effect was warranted. More specifically, this particular constraint can be broken down into sub-constraints identified as the task dimensions previously discussed: discrete/continuous and closed/open. These characteristics could then be subjected to statistical analyses to establish their validity or relation to the attentional focus effect. Despite the fact that individual and environmental constraints were not investigated in this present study, individual sub-constraints were identified as age, sex and level of skill; whereas, environmental constraints included characteristics pertaining to the conditions in which the individual performed the task under.

Attempts to establish a portion of the proposed framework involved similar approaches that are utilized within healthcare to provide research synthesis on the summative and evaluative information of pathology interventions. These approaches include systematic reviews and meta-analyses. To date and to the author’s knowledge, the body of attentional focus literature has not been subject to a comprehensive systematic review and/or meta-analyses. According to Liberati, Altman, Tetzlaff, Mulrow, Gøtzsche, Ioannidis et al. (2009), systematic reviews attempt to gather all empirical evidence that fits pre-specified eligibility criteria in order to address a specific research question. Systematic reviews have key characteristics including: a clear, explicit methodology that is reproducible and follows a set of objectives; an eligibility criteria that used to identify all relevant studies; a validity assessment of the results of included studies; and presentation of the characteristics of included studies in a systematic approach (Liberati et al., 2009). The meta-analyses that were used functioned as an additional step for the systematic review as it quantified the results of individual studies in a standardized metric in order to synthesize results of the included studies. This meant calculating a weighted, mean effect size (i.e. overall summary effect), as well as describing and accounting for differences between included studies.

To provide a specific scope regarding the main purpose of the study, the research question was developed with the PICOS approach (e.g. Liberati et al., 2009) utilized as a reference to frame the question. It asked, does the advantage of adopting an external focus relative to an internal focus vary across randomized trial studies with varying task dimensions (i.e. discrete versus continuous <u>and</u> closed versus open task dimensions) in the acquisition (i.e. immediate performance), retention (i.e. learning), and transfer of motor skills? In order to address this research question, primary and secondary hypotheses were developed. As the secondary hypothesis (which was assessed first to assess the viability of the primary hypothesis), it was hypothesized that the relative advantage of adopting an external focus over an internal focus would hold true across the variety of studies with different tasks and across the learning, the retention of the learning, and the transfer of those tasks. Finally as the primary hypothesis, it was hypothesized that this advantage would vary across studies with different task dimensions in the acquisition, retention, and transfer of motor skills; such that this study-level characteristic could account for a proportion of the dispersion in each of the experimental phases.

CHAPTER 4

METHODS

4.1 Eligibility Criteria

Publications that reported the following were considered for inclusion: an examination of attentional focus effect with explicit internal **and** external focus groups or conditions on sensorimotor task performance and learning in either or all of acquisition, retention, and transfer experimental phases.

In context to motor learning studies, the acquisition phase includes participants being tested with the experimental variable in place. This ‘practice’ phase per se, occurs over a period of trials. In the analysis for the acquisition phase, studies that explicitly reported an acquisition phase were combined with the studies that had no retention or transfer phases; thus, no explicit designation. This was done because these two types of study phases were systematically similar to each other as they both investigated the transient effects of the experimental variable (i.e. the attentional focus instructions). The test for learning of a task in motor learning experiments is the assessment of the individual in a retention or transfer test. Under this paradigm, a skill is considered to be learned only if it is retained (Schmidt & Lee, 2005). More specifically, retention is the persistence of, or lack thereof performance at the behavioural level. In other words, it represents relatively permanent gains or losses in performance gained through practice (i.e. the acquisition phase). On the other hand, transfer can be defined as the ability or measure to perform a highly similar, yet different skill of the original learned skill (Schmidt & Lee, 2005). The retention and transfer phases within a motor learning experiment share commonalities; such that, both of these phases discriminate between the transient and relatively permanent effects an experimental variable has on outcome measure(s) of a skill.

The only fundamental difference between retention and transfer tests in these experiments is that transfer tests require the participant to test with different, yet related tasks or conditions (e.g. changing throwing hands, increasing pace while running etc.). Search limits to English articles as well as full text, peer-reviewed journal articles were imposed for each database. No publication date limitations were imposed to allow inclusion of the studies that conducted experiments pertaining to the attentional focus effect, but did not explicitly state it (i.e. identifying external or internal focus groups/conditions). Participants of any age, sex, skill level, and health status were considered. Finally, all sensorimotor tasks were considered in the review, as well as their outcomes; however, kinematic outcome measures were excluded due to the high task specificity and complexity of these types of outcomes.

4.2 Data Sources and Search Methods

A comprehensive literature search, identification, and retrieval of primary studies pertaining to the attentional focus effect were conducted by the guidance, structure, and key characteristics of a systematic review. The procedures of the literature search followed methods that are adopted from the Cochrane Handbook for Systematic Reviews of Intervention (Higgins & Green, Eds, 2008). This search was applied to databases relevant to the motor learning literature: PubMed (1971-Present), CINAHL (1976-Present), Proquest Nursing and Allied Health Source (1973-Present), PsychINFO (2006-Present), and SPORTDiscus (1934-Present) electronic databases. The first and only search was run on March 3, 2015. The search did not include a grey literature search; that is, seeking out possible unpublished work (i.e. Master's theses, dissertations) in university databases as well as contacting authors of included papers or experts in the field to request possible unpublished work. The search strategy included a combination of keywords such as 'attentional focus', 'focus of attention', 'motor learning', 'motor performance', 'external foc*', 'internal foc*', 'constrained action hypothesis', 'instructions', 'movement effects', and 'body movements' (see appendix I).

4.3 Article Screening and Selection

To mitigate article selection bias, eligibility assessment of the studies was performed by independent two reviewers. One reviewer has extensive knowledge regarding the area of literature and the other reviewer was a compensated graduate student who had some prior knowledge of the research field. Working independently and in an un-blinded standardized manner, the reviewers initially screened the titles and abstracts of the articles gathered from the electronic databases. To quantify the agreement between the reviewers in this stage to ensure adequate inter-rater reliability for the article screening and selection, a Kappa statistic was calculated. Developed by Orwin (1994), the Kappa statistic measures the agreement between two reviewers with the benchmarks of 0.49-0.59, 0.60-0.74, and 0.75 and above signifying fair, good, and excellent agreement, respectively. For this initial screening reliability test, the 100 articles from the study identification stage were used. The computations revealed a Kappa statistic of 0.75, which indicated excellent inter-rater reliability (see appendix II). Because of the excellent inter-rater reliability, the articles to be screened were subsequently divided equally among the two reviewers.

4.4 Data Extraction

A developed extraction form adapted from Sheri Parks' Meta-Analysis of Sport Expertise (e.g. Thomas, et al., 2011) was employed to obtain data regarding descriptive information about each study, information about the motor task performed, the experimental design, the independent and dependent variables used in each task(s) of each study, and the participants in each study (see appendix III). The form was electronically transformed into MS Access for ease of use and storage of information. This form was pilot-tested on three randomly-selected included studies and refined accordingly. The two reviewers extracted the data independently, and then combined their databases into a consensus database. Disagreements between reviewers that arose when combining the databases into a consensus database were resolved via consensus. If the reporting of included studies appeared to be incomplete (i.e. missing group/condition means and standard deviations, effect sizes that could be readily transformed into Cohen's *d*, and exact p-values), the corresponding primary authors were contacted for appropriate data retrieval.

The quality assessment of individual studies was addressed within the extraction form. That is, for each included study, the external and internal focus instructions were examined closely to ensure they fit the inclusion criteria. In addition, this assessment addressed if studies implemented techniques to control for threats to internal validity. These techniques include random placement of participants in independent groups design or counterbalancing participants in dependent groups design (i.e. controlling for history and maturation) and random ordering or presentation of tasks (i.e. order and learning effects) (Thomas et al., 2011).

Other concerns addressed within the quality of assessment of individual studies were the assumption of normality and sphericity of variance of datasets. Higgins, Thompson, & Spiegelhalter (2009) suggested that normality of data is essential as computations of the estimate of true effect in a random-effects model are based upon data that has a normal distribution. Moreover, Morris (2008) suggested that it is important to preserve the homogeneity of variance between groups and conditions within studies as formulas for estimating effect size variance have been derived under this assumption. Morris (2008) also suggested that when variance are heterogeneous across condition within a study, the sampling variance will be underestimated, and ultimately will lead to an increase chance of making a type 1 error. Therefore, as a precaution, these studies were not included.

4.5 Data Analysis and Synthesis

4.5.1 Estimating Effect Sizes of Individual Studies

All statistical significance analyses in subsequent tests were based on $\alpha < .05$. All relevant information extracted from studies and obtained through primary author contact was inputted and analyzed with Comprehensive Meta-Analysis (CMA) software. The effect sizes obtained or calculated in each of the individual studies were representative of the <u>standardized mean difference</u> between the internal and external focus groups/conditions. The effect sizes were obtained or calculated with related statistics from the included studies were transformed in the metric of Cohen's *d*, which represents the estimated standardized mean difference, δ (Cohen, 1988).

Due to the variation of studies reporting various statistics and their design, Cohen's *d* was estimated using various techniques. For independent groups design studies, they included using: the means and standard deviations of independent groups study design, sample size (of each group) and t-value, means and t-values, mean change and standard deviation of difference of pre-post independent groups, and mean change and standard deviation within groups of pre-post independent groups. For the paired-groups design they included: means and t-value, sample size (total) and t-value, means and exact p-value. Note: for the paired-groups computations, the R-value was set at 0.5 since it was not reported nor obtained by the contacted authors.

To compute *d* in studies who reported the means and standard deviation of the independent groups,

$$d_{independentgroup1} = \frac{xbar_1 - xbar_2}{S_{within}}$$

(Eq. 1)

where $Xbar_1$ and $Xbar_2$ represent the means of independent external and focus groups, respectively. S_{within} represents the within-focus group standard deviation, pooled across groups

$$S_{within} = \sqrt{\frac{(n_1 - 1)S_1^2 + (n_2 - 1)S_2^2}{n_1 + n_2 - 2}}$$

(Eq. 2)

where n_1 and n_2 are the sample size in each focus group and s_1 and s_2 are the standard deviations of the two groups. Lastly, the variance of $d_{independentgroup1}$ (V_d) was computed as

$$V_d = \frac{n_1 + n_2}{n_1 n_2} + \frac{d^2}{2(n_1 + n_2)}$$

(Eq. 3)

whereas the standard error (SE_d) was the square root of V_d. To compute d in studies that use the sample size and t-values of the independent groups (similar to means and t-value of independent groups),

$$d_{independentgroup2} = \frac{t}{\left(\left(\sqrt{harmonicN}\right) \div \left(\sqrt{2}\right)\right)}$$

(Eq. 4)

where t is the t-value and $harmonicN$ was,

$$harmonicN = \frac{(2 * n1 * n2)}{(n1 + n2)}$$

(Eq. 5)

where n1 and n2 are the sample size in each group. The standard error of $d_{independentgroup2}$ was computed as

$$SE_{dindependentgroup2} = \sqrt{\left((1/n1) + (1/n2) + (dIG2^2) \div \left(2 * (n1 + n2)\right)\right)}$$

(Eq. 6)

where n1 and n2 are the sample size in each group. Lastly, to compute the variance, it was the square of $SE_{dindependentgroup2}$. To compute d for studies who reported the mean change and standard deviation of difference of pre/post independent groups,

$$d_{changediff} = \frac{mean\Delta 1 - mean\Delta 2}{SD_{changepooled}}$$

(Eq. 7)

where $mean\Delta1$ is the mean difference in group 1, $mean\Delta2$ is the mean difference in group 2, and $SD_{changepooled}$ was,

$$SD_{changepooled} = \sqrt{\left(\frac{(n1-1) * SD_{Change1}{}^{2} + (n2-1) * SD_{Change1}{}^{2}}{n1+n2-2}\right)}$$

(Eq. 8)

where *n*1 and *n*2 are the sample sizes in both groups, $SD_{Change1}$ and $SD_{Change2}$ are the standard deviation of difference in group 1 and group 2, respectively. The standard error of $d_{changediff}$ was computed as,

$$\mathrm{SE}_{dchangediff} = \sqrt{\frac{\left((1 \div n1) + (1 \div n2) + d_{changediff}{}^{2}\right)}{2 * (n1+n2)}}$$

(Eq. 9)

where *n*1 and *n*2 are the sample sizes in both groups, and $dchangediff$ is the standardize difference in change. Lastly, to obtain the variance, it was the square of $\mathrm{SE}_{dchangediff}$. To compute *d* for studies who report the means and t-value for paired groups,

$$SD_{paireddiff} = \frac{t_{observed}}{\sqrt{n}}$$

(Eq. 10)

where $t_{observed}$ is the paired t-value between the two groups and n is the number of pairs. To obtain the standard error of$SD_{paireddiff}$, it was computed as,

$$SE_{SDpaireddiff} = \left(1/\sqrt{n}\right) * \sqrt{(1 + SD_{paireddiff}{}^{2}/2)}$$

(Eq. 11)

where n is the number of pairs. To transform $SDpaireddiff$ into a comparable independent standardized mean difference,

$$SD_{diff} = SD_{paireddiff} * \sqrt{2 * (1 - imputedR)}$$

(Eq. 12)

where $imputedR$ is the correlation between the paired groups (set at 0.5). To transform the $SE_{SDpaireddiff}$ into a comparable independent standard error,

$$SE_{SDdiff} = \sqrt{(\frac{1}{n} + \frac{SE_{SDpaireddiff}{}^2}{2n})} * \sqrt{(2 * (1 - imputedR))}$$

(Eq. 13)

where, n is the number of pairs and $imputedR$ is the correlation between the paired groups (set at 0.5). Lastly, to obtain the variance, it was the square of SE_{SDdiff}. To compensate for the overestimation of δ, especially in small sample sizes, Hedge's *g* was utilized (Hedges, 1981). Converting from *d* to *g* required multiplication of *d* by a conversion factor, *J* that was computed by

$$J = 1 - \frac{3}{4df - 1}.$$

(Eq. 14)

at which *df* is the degrees of freedom used for the computation of S_{within}. To obtain the variance of *g* (V_g), *J* is squared, then multiplied by V_d. Lastly, standard error of *g* (SE_g) was obtain by taking the square root of V_g..

It is important to note that the majority of the included studies have what Borenstein et al. (2009) referred to as 'complex data structures'. These included studies that have multiple independent subgroups, comparisons, and outcomes. To control for the complex data structures, each meta-analyses for each experimental phase was conducted with independent subgroups as the unit of analysis and collapsing across multiple comparisons and outcomes. The subgroups were treated as the unit of analysis, as they provided unique information (i.e. increased amount of study weight) to the analyses. In order to compute an overall summary effect for multiple comparisons and/or outcomes in an applicable study, the fact that these comparisons and outcomes were related (i.e. share a degree of dependency to each other) need to be accounted for. Since these correlation values were unknown, the means of the multiple comparisons and/or outcome measures were used. This method allowed for a conservative estimate of the overall summary effect's variance via setting the variance between multiple comparisons and/or outcomes at r = 1.00.

4.5.2 Overall Summary Effect

Individual study effect estimates were combined into the overall summary effect. This mean effect size represents the weighted, pooled effect size of all included studies. Study weight is the inverse of the inverse of the within and between study variance of an individual study (Borenstein et al., 2009). This method allows for more precise study to contribute more towards the estimation of the overall summary effect. The meta-analyses for each experimental phase (i.e. acquisition, retention, and transfer) were performed based on the random-effects model. This model has two assumptions: that the true effect (i.e. true study dispersion from the overall summary effect) is normally distributed and that there may be different effect sizes underlying different studies as they are heterogeneous in terms of participants and interventions (Borenstein et al., 2009).

Adopting this model allows for individual study effects to vary from study to study (i.e. heterogeneity) and warrants subsequent analyses to address the heterogeneity. This differs from a fixed-effect model that makes the assumption that all studies share a common effect size (Borenstein et al., 2009). The initial syntheses of the data included calculating the overall summary effect's related statistics such as its variance, standard error and lower and upper 95th percentile confidence intervals. The overall summary effect was computed as

$$M^* = \frac{\sum_{i=1}^{k} W_i^* Y_i}{\sum_{i=1}^{k} W_i^*}$$

(Eq. 15)

such that the numerator is the sum of the products of effect size (Y_i) multiplied by study weights (W_i) and the denominator is the sum of the study weights (W_i). The study weight allocated to each study was determined by

$$W_i^* = \frac{1}{V_{Y_i}^*}$$

(Eq. 16)

such that V_{yi} is the within-study variance for study i plus the between-studies variance (T^2). The estimated variance (V_m) of the overall summary is the reciprocal of the sum of study weights, whereas the estimated standard error (SE_m) is the square root of (V_m). The viability of the null hypothesis (i.e. that the overall summary effect is zero) was subjected to statistical significance testing via the z-test of distribution.

4.5.3 Reporting Bias Analyses

To assess the validity of the syntheses of results, reporting bias analyses conducted in the CMA software were implemented to address the following concerns:

- Is there evidence of reporting bias?
- Is it possible that the entire effect is a product of the bias?
- How much of an impact does the bias have if it is present?

The first concern was addressed through the visual representation of a funnel plot. First identified by Light and Pillemer (1984), this plot displays the relationship between study size/variation and study effect, where they reside on the y and x-axis, respectively. Since sampling error is presumed to be random, in the absence of reporting bias, the studies will be distributed symmetrically about the overall summary effect. More specifically, the larger studies (i.e. with small amount of variation) are plotted close to the overall summary effect evenly on both sides near the top of the graph (Borenstein et al., 2009). Whereas, the smaller studies (i.e. with large amount of variation) are dispersed along the bottom of the graph, evenly on either sides of the overall summary effect. In the presence of publication bias, a type of reporting bias that is most common, the funnel plot will appear asymmetrical with the studies following the model of publication bias (Borenstein et al., 2009). In this model, symmetry appears at the top of the plot, a few studies missing in the middle, and more studies missing near the bottom. According to the model, large studies are more susceptible to be published regardless of statistical significance. This is because they require substantial amounts of resources and time. Medium size studies are at risk for being lost because robust effects will produce statistically significant results with a moderate sample size. Lastly, smaller studies are at the greatest risk of being lost with the largest effects having the greater chance of being published and small and moderate effect having the greater chance of being unpublished (Borenstein et al., 2009). Determining whether the funnel plot is asymmetrical requires a high degree of subjectivity; therefore, Egger, Davey-Smith, Schneider, & Minder's (1997) Regression Intercept was used to formally test the funnel plot for asymmetry for statistical significance.

To address the second concern (i.e. is it possible that the entire effect is a product of the bias?), Rosenthal's (1979) Fail-Safe *N* was employed. This statistical method uses the z-value for the observed studies to compute how many missing studies are needed to be incorporated in the analysis to 'nullify' the effect (Borenstein et al., 2009). If a considerable amount of studies are needed to raise the p-value above the alpha level (e.g. $z=1.96$, $p=0.05$), then there is no concern about the overall summary effect representing truly the mean effect size of studies. Conversely, if there is a small amount of studies that are needed to raise the p-value, then there may be reason to suggest the overall summary effect is an artefact of bias.

Lastly, to address the third concern (i.e. how much of an impact does the bias have if it is present?), Duval and Tweedie's (2000a, 2000b) Trim and Fill method was utilized to determine the unbiased overall summary effect in the presence of publication bias. The Trim and Fill method removes the most extreme small studies from the positive side of the funnel plot and uses an algorithm to re-compute the effect sizes at iterations until the funnel plot is symmetric about the new effect size. This yielded an unbiased estimate of the effect size. If this method identifies missing studies to the left and to the right of overall summary effect, an addition funnel plot with both the observed and imputed studies was created to visualize the overall summary effect shift when the imputed studies were added.

4.5.4 Assessing Heterogeneity

Tests for assessing heterogeneity were implemented to describe and quantify the dispersion of individual study effect from the overall summary effect (Borenstein et al., 2009). In this study, it was used to describe the change in magnitude of the attentional focus effect in all three of the experimental phases. The total dispersion of all included studies was quantified into the statistic Q

$$Q = \sum_{i=1}^{k} W_i (Y_i - M)^2$$

(Eq. 17)

where W_i is the study weight ($1/V_i$), Y_i is the study effect size, M is the overall summary effect and k is the number of studies" (Borenstein et al., 2009, p. 109). Finding Q allowed for the partition of variance into ratio of observed variation to the random study error. The expected value (based on the assumption that all studies share a common effect size) of Q was determined by the degrees of freedom $df = k - 1$, where k is the number of studies. This expected value was subsequently subjected to a central chi-square test of distribution to test if the heterogeneity is statistically significant (i.e. rejecting the null hypothesis that all studies share a common effect size). To estimate the true dispersion tau-squared (τ^2) and to obtain an absolute value such that the variance can be used to describe the distribution of individual study effect sizes about the overall summary effect, the T^2 statistic was computed as an intermediate statistic (i.e. in the metric of the effect size)

$$T^2 = \frac{Q - df}{C}$$

(Eq. 18)

where the numerator $Q - df$ is the WSS excess and the denominator

$$C = \sum W_i - \frac{\sum W_i^2}{\sum W_i}$$

(Eq. 19)

where W_i is the study weight ($1/V_i$). Lastly, to represent the proportion of estimated true dispersion to total dispersion, the descriptive I^2 statistic was computed such that I^2 equals

$$I^2 = \left(\frac{Q - df}{Q}\right) \times 100\%$$

(Eq. 20)

The I^2 statistic represents the proportion of the observed variance of the overall summary effect that reflects real differences in effect size between studies (Borenstein et al., 2009). Forest plots were constructed for each meta-analysis to illustrate the estimated effect and confidence intervals of individual studies as well as the overall summary effect and its confidence interval for all three experimental phases.

4.5.5 Subgroup Analyses

The subgroup analyses served two functions; that were to yield a statistical interpretation of the main effects of subgroups on the overall summary effect (i.e. asking whether the difference between the means effect of subgroups is related to the actual overall summary effect), and establish the proportion of explained variance of the subgroup mean difference to the overall summary effect. Although information was collected for each of the proposed constraints (i.e. age, skill level, sex, and health status for the individual constraint; and environmental characteristics for the task constraints), the subgroup analyses only addressed the task constraint and its interaction with the attentional focus effect.

The subgroup analyses for each experimental phase were computed using a mixed effect model. That is, the assumption is that studies within each subgroup do not share a common effect size (i.e. random effects model) and the assumption that the subgroups themselves were not sampled at random from a larger sampling pool (i.e. fixed effect model) In other words, there were only two distinct classifications for task dimension subgroup (i.e. discrete and continuous).

An additional assumption was made, such that the true between-studies variance was the same for all subgroups. The estimates of tau squared (τ^2) were computed within subgroups, then pooled, and used as the estimate for all subgroups. Computations for each of the task dimension subgroups for overall summary effect and the relating statistics (variance, standard error) were made. In addition, statistical heterogeneity was assessed and reported within each subgroup (Eq. 8 through 11). Statistical significance of each of the subgroups' overall summary effect (i.e. testing the null hypothesis that the overall summary effect is zero) was determined using the z-test of distribution and calculations of the lower and upper confidence intervals marked at the 5th and 95th percentiles, respectively.

To compare the effects of the subgroups (i.e. to assess whether the subgroup means significantly differ from each other, thus relating to the overall summary effect, a Q-test based on analysis of variance was utilized,

$$Q^*_{within} = \sum_{j=1}^{p} Q^*_j$$

(Eq. 21)

where p is the number of subgroups and since $Q = Q_{between} + Q_{within}$, $Q_{between}$ can be determined via

$$Q_{between} = Q - Q_{within}$$

(Eq. 22)

It is important to note that Q is the weighted sums of squares of <u>all effects</u> about the overall summary effect; $Q_{between}$ is the weighted sums of squares of the subgroup means about the overall summary effect; and Q_{within} is the sum of the weighted sums of squares for all studies about their respective subgroup overall summary effect (Borenstein, Hedges, Higgins, & Rothstein, 2009). Furthermore, computations for the proportion of the explained variance via subgroup membership were made. Utilizing an adapted version of the R^2 index

$$R^2 = 1 - \left(\frac{T^2_{within}}{T^2_{total}} \right)$$

(Eq. 23)

where, the numerator represents the between-studies variance within subgroups, and the denominator represents the total between-studies variance (i.e. within-subgroups plus between-subgroups)" (Borenstein, et al., 2009).

CHAPTER 5

RESULTS

5.1 Study Selection

The electronic search strategy employed in PubMed (2246 articles), CINAHL (582 articles), Proquest Nursing & Allied Health Source (1298 articles), PsychINFO (245 articles), and SPORTDiscus (841 articles) yielded a total of 5412 citations (Figure 2). After accounting for duplicate records within each of the databases, 3505 hits remained. Of these, 3352 studies were discarded after initial screening and selection of abstracts and titles as they did not meet the inclusion criteria (i.e. explicit comparison of the external and internal focus). Of the remaining 153 studies, 100 articles were excluded due to various reasons.The first reason pertained to studies whom lacked sufficient information for calculating effect size and variance (n = 46); contact was made to 34 authors for further information, with 28 of those authors responding with the requested additional information. The second reason pertained to studies failing to qualify the eligibility criteria after thorough investigation of the article (n = 37); these studies did not investigate the explicit external and internal focus groups/conditions. The third reason pertained to studies whom failed to meet the quality assessment requirements of normality and sphericity of variance of datasets (n = 17). However, it is important to note that all studies met other quality assurance requirements of random placement of participants in independent groups design, counterbalancing conditions in dependent groups design, and randomizing the ordering of the task. The final reason of exclusion related to one study who failed to meet the English language requirement (n = 1).

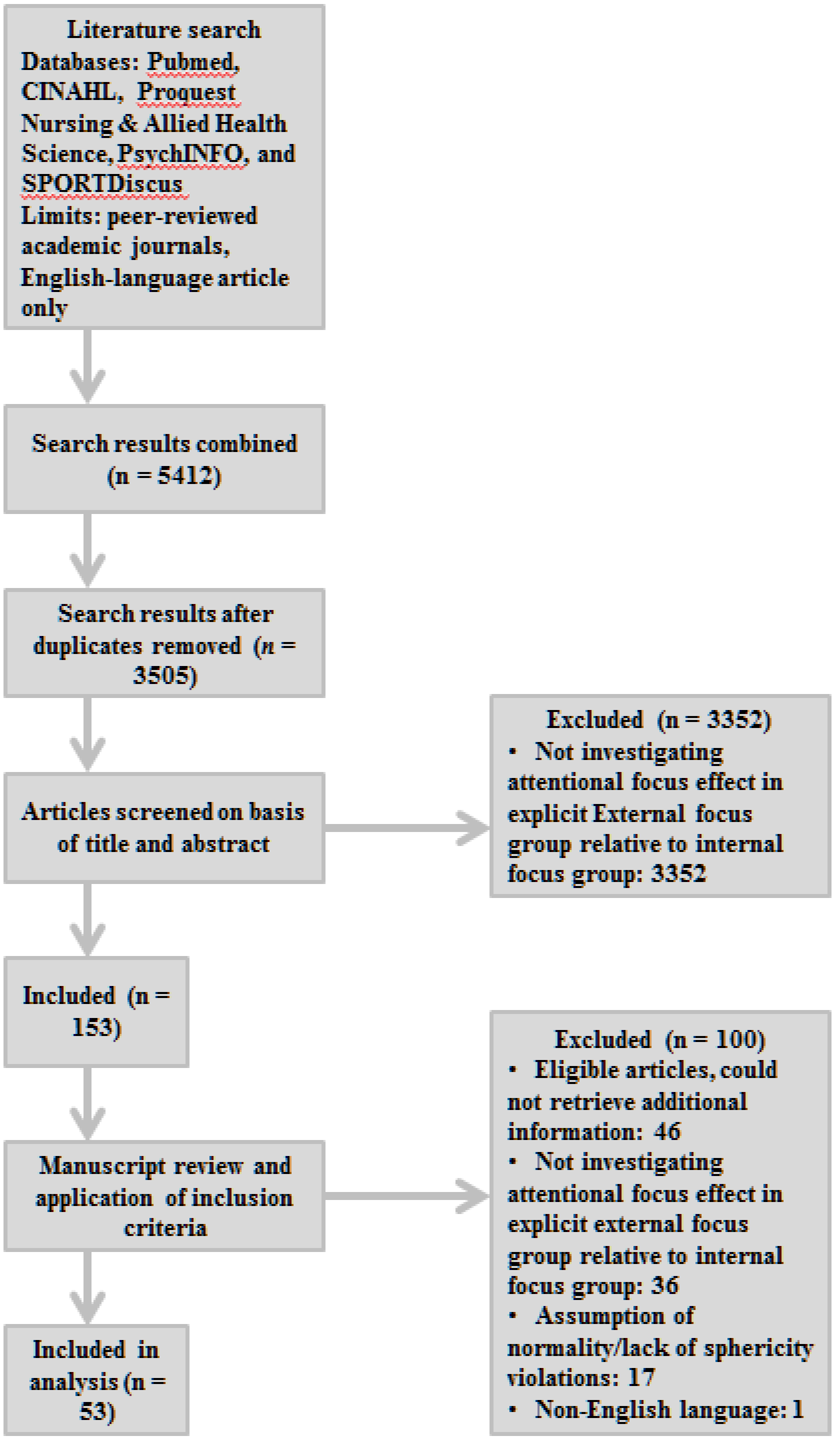

Figure 2. <u>Flow of studies throughout the identification, screening, eligibility, and included phases of the systematic review.</u>

Table 1. **Included studies descriptive characteristics I.**

Study	Task	Task Dimension	External Focus Group/Condition* Size (*n*)	Internal Focus Group/ Condition* Size (*n*)	External Focus Group Instructions	Internal Focus Group Instructions
Bell & Hardy (2009)	Golf chip shot (20 m)	Discrete	11	11	PROXIMAL EXT: "focus on the position of the clubface through the swing, keeping the clubface square through impact"; DISTAL EXT: "focus explicitly on the flight of the ball after it had left the clubface and the direction they intended to set the ball"	"Focus on the motion of the arms during the swing and specifically to maintain the hinge in the wrists through impact"
Castaneda & Gray (2007)	Baseball batting simulation	Discrete	8*	8*	SKILL EXT: "judge the direction of the bat's movement at the instant in time auditory tone was presented"	SKILL INT: "judge whether their hands were moving upwards/downwards at the instant in time that auditory"
Chiviacowsky, Wulf, & Avila (2013)	Bean bag toss	Discrete	11	13	"Focus their attention to the movement of the beanbag while throwing"	"Focus their attention on the movements of their throwing hand"
Chiviacowsky, Wulf, & Wally (2010)	Stabilometer	Continuous	16	16	"Focus their attention on keeping the markers in front of their feet horizontal"	"Focus their attention on keeping their feet horizontal"
Chow, Woo, & Koh (2014)	Running (1 min)	Continuous	8	8	"Land with the coloured portion of your shoe"; "strike your foot in line with the virtual line"	"Only put weight on the ball of your feet when you land"; "push off by using the ball of your feet"
Christina & Alpenfels (2014, experiment 1)	Golf swing with 6 iron	Discrete	15	15	"Swing the club head parallel to a swing-path alignment rod positioned on an inside-out path from 8 to 2 o'clock relative to the target-line alignment rod, @ 12 o'clock"	Instructed to "bring their right elbow to their right side on the first part of the down-swing to help them learn to swing on an inside-out path

						relative to the target-line alignment rod”
Christina & Alpenfels (2014, experiment 2)	Golf swing with driver	Discrete	13	13	“Swing the club head parallel to a swing-path alignment rod positioned on an inside-out path from 8 to 2 o'clock relative to the target-line alignment rod, @ 12 o'clock”	Instructed to “bring right elbow to their right side on the first part of the down-swing to help them learn to swing on an inside-out path relative to the target-line alignment rod”
Gokeler, Benjaminse, Welling, Alferink, Eppinga & Otten (2014)	Single leg hop	Discrete	8	8	‘‘Jump as far as you can. While you are jumping, I want you to think about pushing yourself off as hard as possible from the floor’’	"Jump as far as you can. While you are jumping, I want you to think about extending your knees as rapidly as possible’’
Jackson & Holmes (2011)	Stabilometer	Continuous	9, 9	9, 9	“Focus on keeping the boards as level as possible”; “board angle being measured throughout trial for performance/feet were being measured throughout trial for performance”	“Focus on keeping their feet as level as possible”; “board angle being measured throughout trial for performance/feet were being measured throughout trial for performance”
Jarus, Ghanouni, Abl, Fomenoff, Lundberg, Davidson, Caswell, Bickerton, & Zwicker (2015)	Manual cursor tracking via joystick	Continuous	7, 6	6, 7	“Focus on the computer screen and movements of the joystick while tracking the target”	“Focus on the movement of their hand, wrist and arm while performing the tracking task”
Kal, van der Kamp & Houdijk (2013)	Continuous leg extension/flexion	Continuous	30*	30*	“Focus on alternatively placing the foot in front of and behind the line”	“Focus on flexing and extending their leg”
Kalkhoran, &	Basketball	continuous	15	15	“Focus attention to the path and the	“Focus attention on

Shariati (2014)	dribbling task				location of obstacles”	hand movements during dribbling” – moment of contact, controlling and guiding the ball
Kasper, Elliott & Giesbrecht (2012)	Golf putt	Discrete	12	13	“Swing head of club straight back, no further back than it goes forward on follow-through”; “better for club to have shorter follow-through”; “accelerate club head straight through the ball”; “finish with face of club head pointing straight in the direction of the target”	“Swing arms straight back, no further back than they extend forward on follow-through”; “better for the arms to have shorter follow-through”; “accelerate arm swing thru the contact in a straight motion”; “finish with arms pointing straight in the direction of the target”
Keller, Lauber, Gottschalk & Tabue (2014)	Jump height	Discrete	19*	19*	“When you are attempting to jump as high as possible, I want you to focus your attention on jumping as close to the ball as you possibly can”	“When you are attempting to jump as high as possible, I want you to focus your attention on extending your legs as rapidly as possible”
Klostermann, Kredal & Hossner (2014)	Golf putting (3 m)	Discrete	12*	12*	“Hit the target cross as accurately as possible and, in particular, mentally pat attention to the feeling when the ball leaves the head of the putter. By this, I mean the first feedback on putting success (feeling virtually no collision between the ball and putter head) or failure (feeling a noticeable collision between the ball and putter head”	“Hit the target cross as accurately as possible and, in particular, mentally pay attention to the feeling at the near reversal point of the swing. By this, I mean the rhythm and speed of the swing between backswing and forward swing”
Kukar, Zia, Sehgal, &	Dart throwing	Discrete	12	12	“Bring dart to eye level, feel it in front”; “look at the centre; bring dart towards	“Concentrate on finger motions and correct

Khushwaha (2013)					right ear and throw the dart while throwing”	position, pay attention to grasp, bending or straightening of elbow”; “bring hand back, when throwing straighten all fingers to face forward, straighten elbow”
Land, Frank & Schack (2014)	Golf putting (3 m)	Discrete	12*	12*	“Focus on the proper trajectory and speed of the ball rolling to the hole”; given a visual reminder of 'speed of ball roll'	“Focus on the swing of their arms and hands”; “maintain firm wrists during the stroke”
Land, Tenenbaum, Ward & Marquardt (2013)	Golf putting (3 m)	Discrete	10	10	“Focus on the direction and speed of the ball rolling to the golf hole”	Identified as the control: instructed to putt as normal; however it was after that they had adopted 'movement-related' foci
Landers, Wulf, Wallman, & Guadagnoli (2005)	Stabilometer	Continuous	10*	10*	“Stand quietly with your eyes A) open or B) closed and concentrate on putting equal pressure on rectangles”; “platform may move, stand quietly with eyes open and concentrate on keeping rectangles level”	“Stand quietly with your eyes A) open or B) closed and concentrate on putting equal pressure on feet”; “platform may move, stand quietly with eyes open and concentrate on keeping feet level”
Laufer, Rotem-Leher, Ronen, Khayutin & Rozenburg (2007)	Stabilometer	Continuous	20	20	“Keep your balance by stabilizing the platform”	“Keep your balance by stabilizing your body”
Lidor, Ziv, & Tenenbaum (2013)	Ball throwing	Discrete	25, 27, 27	25, 27, 27	“Focus their attention away from their body and task, and to maintain their focus on one specific external cue”; asked to “clear their mind and focus solely on one external event”	“Focus attention on internal processes related to the throwing act”; directed to pay attention to and “focus on the mechanics of

						their motion, and to feel their movements during the throw”
Lohse (2012)	Isometric force production: plantar flexion	Continuous	12	12	“Point toward the force platform”; “mentally focus on push of foot against platform”; “if produce too much force, focus on pushing platform less”; “if produce too little force, focus on pushing platform harder”	“Point towards experimenter's posterior calf”; “mentally focus on the muscle of your calf”; “if produce too much force contract muscle less”; “if produce too little force, contract muscle more”
Lohse & Sherwood (2011, experiment 1)	Wall-sit	Continuous	12	12	**ASSOCIATIVE/DISSOCIATIVE EXT**: “Visually focus on fixation point on wall”; “mentally focus on drawing imaginary line between markers from knee to **HIP**/**PYLONS** in front trying to keep lines parallel to floor to minimize up/down movement”	“Visually focus on the fixation point on wall”; “mentally focus on position of thighs, trying to keep them parallel to floor to minimize up/down movement”
Lohse & Sherwood, (2011, experiment 2)	Wall-sit	Continuous	20	20	Same as experiment 1	Same as experiment 1
Lohse, Sherwood, & Healy (2010)	Dart throwing	Discrete	12*	12*	“Focus on the flight of the dart”; “when off target, try to correct the flight of the dart”	“Focus on the motion of your arm”; “when off target, try to correct the motion of your arm”
Lohse, Sherwood, & Healy (2011)	Isometric force production: plantar flexion	Continuous	12*	12*	“Mentally focus on push of foot against platform”; “if produce too much force, focus on pushing against platform less”; “if produce too little force, focus on pushing platform harder”	“Mentally focus on pushing with the muscle of their calf against platform”; “if produce too much force, focus on contracting the muscle less”; “if produce too little force, focus on contracting the muscle more”

Lohse, Sherwood, & Healy (2014, experiment 1)	Dart throwing (2.37 m)	Discrete	20	20	“Focus on the flight of the dart”; “when off target, try to correct the flight of the dart”	“Focus on the motion of your arm”; “when off target, try to correct the motion of your arm”
Lohse, Sherwood, & Healy (2014, experiment 2)	Dart Throwing (2.37 m)	Discrete	20	20	“Focus on the flight of the dart”; “when off target, try to correct the flight of the dart”	“Focus on the motion of your arm”; “when off target, try to correct the motion of your arm”
Makaruk, Porter, Czaplicki, Sadowki, & Sacewicz (2012)	Counter-movement jump, drop-jump, standing long-jump	Discrete	12	12	“Touch the hanging ball” [COUNTER-MOVEMENT JUMP, DROP-JUMP]; “jump behind the line” [STANDING LONG-JUMP];	“Reach your fingers as high as you can” [COUNTER-MOVEMENT JUMP, DROP-JUMP]; “reach your heels as far as you can” [STANDING LONG-JUMP]
Makaruk, Porter, & Makaruk (2013)	Shot put	Discrete	30*	30	“When you are putting the shot, focus on hitting the visible target” (a round white target 40 cm high place at the participant's personal best)	“When you are putting the shot, focus on extending your arms rapidly”
Marchant, Clough, Crawshaw, & Levy (2009)	Dart throwing (3.66 m)	Discrete	32*	32*	“Focus on the center of the dartboard, and toss the dart when focused”	“Focus on the movement of the arm as the dart is drawn back and during the throw”; “focus on the release of the dart at the end of the throw”
Marchant, Greig, & Scott (2009)	Single elbow flexions	Discrete	25*	25*	Directed attention toward the movement of the bar being moved: “focus upon the movement of the crank hand bar during the lift”	Directed attention toward the movement of the arm and muscles: “focus upon the movement of your arm and muscles during the lift”
Marchant, Grieg, Bullough &	Assisted bench press, bench press, free squat	Discrete	23*, 17*, 17*	23*, 17*, 17*	EXERCISE ONE and TWO: “Focus on moving and exerting force through and against the barbell”; EXERCISE	EXERCISE ONE and TWO: “Focus on moving and exerting

Hitchen (2011)					THREE: "Focus on moving and exerting force through and against the barbell"	force with your arms"; EXERCISE THREE: "Focus on moving and exerting force with your legs"
Maurer & Munzert (2013, experiment 1)	Free throw shooting	Discrete	23*	23*	Familiar/unfamiliar movement aspects: "basket", "front of rim", "middle of rim", "ball falling through basket", "ball flight trajectory", "highest point of ball flight", "rectangle of board", "back part of rim";	Familiar/unfamiliar movement aspects: "straightening arm", "snapping wrist", "straightening legs", "fluent leg-arm coordination", "elbow under ball", "feeling ball's weight", "weight on both feet"
Maurer & Munzert (2013, experiment 2)	Golf putting	Discrete	14*	14*	"Direct attention toward club head movement: it moves on virtual line between ball & middle of hole [EXT 1]/continues moving towards target after hitting ball" [EXT 2]	"Direct attention towards triangle formed via arms/shoulders: it moves smooth & pendulum-like" [INT 1]; "direct attention to wrists; they remain fixed while moving" [INT 2]
Munzert, Maurer, & Reiser (2014)	Golf putting (4.50 m)	Discrete	15	15	"Focus on the goal! Pay attention to a point about 50 cm beyond the putt that lies on the course of the golf ball toward the goal"	"Focus on your movement! Pay attention to performing a pendulum-like movement"
McNevin, Weir, & Quinn (2013)	Postural and supra-postural task (manual tracking)	Continuous	12*	12*	"Focus on keeping the tip of the stylus centered within the target"	"Focus on keeping the knuckle of their thumbs centered within the target"
Mullen, Faull, Jones, & Kingston (2012)	Driving simulation	Continuous	8	8	"Focus on the planned trajectory of the car through next bend as they approached it"; "use the cue outside (track), inside (apex of corner), outside (outside track) as the ideal planned	"Focus on using outside hand to turn into corner most efficiently"; "use the cue outside hand to guide their hand

					movement of the car”	movements”
Neumann & Brown (2013)	Sit-ups	Discrete	23*	23*	Induced via video modelling: “make your movements smooth, make your movements flow”	Induced via video modelling: “focus on your stomach muscles, feel your stomach muscles working”
Polskaia, Richer, Dionne, & Lajoie (2015)	Stabilometer	Continuous	20*	20*	“Concentrate on minimizing the movement of the markers placed on their hips as much as possible”	“Concentrate on minimizing the movement of their hips as much as possible”
Porter, Ostrowski, Nolan, & Wu (2010)	Standing long jump	Discrete	60	60	“When attempting to jump as far as possible, I want you to focus your attention on jumping as far past the start line as possible”	“When attempting to jump as far as possible, I want you to focus your attention on extending your knees as rapidly as possible”
Rotem-Lehrer & Laufer (2007)	Balance training	Continuous	16	20	“Keep your balance by stabilizing the platform”	“Keep your balance by stabilizing your body”
Saemi, Porter, Wulf, Ghotbi-Varzaneh, & Bakhtiari (2013)	Throwing task (3 m)	Discrete	10	10	“With dominant hand, as accurately as possible throw it toward the target while concentrating on the ball, particularly the landing location of the ball”	“With dominant hand, as accurately as possible throw it towards the target while concentrating on the motion of your hand and wrist that is throwing the ball”
Shafizadeh, Platt, & Bahram (2013)	Dart throwing (2 m)	Discrete	12	12	“Aim the dart at the bulls-eye”; “move dart back and front”; “focus on centre of target and release”; “transfer weight to front line”	“Stand with preferred arm in front”; “bend your elbow”; “extend your elbow”; “transfer body weight to front leg”
Shea & Wulf (1999)	Stabilometer	Continuous	8	8	NO FEEDBACK EXT: “try to keep the two yellow lines in front of their feet at the same height”; FEEDBACK EXT: “pink line on the screen represented the	NO FEEDBACK INT: “try to keep their feet at the same height”; FEEDBACK INT: “pink

					yellow lines in front of their feet"	line on the screen should be thought of as representing their feet"
Sulewski, Tripp, & Wikstrom (2012)	Balance training	Continuous	8	8	"Keep your balance by stabilizing the platform"	"Keep your balance by stabilizing your body"
Vance, Wulf, McNevin, Tollner & Mercer (2004, experiment 1)	Elbow flexion/extension	Discrete	11*	11*	"Concentrate on the curl bar"	"Concentrate on their biceps muscles"
Wulf & Dukek (2009)	Jump and reach	Discrete	10*	10*	"Concentrate on the rungs of the Vertec, reaching as high as possible"	"Concentrate on the tips of their fingers, reaching as high as possible during the jumps"
Wulf & Su (2007, experiment 1)	Golf chip shot (15 m)	Discrete	10*	10*	"Focus directed toward the pendulum-like motion of the club"	"Focus directed at the swinging motion of their arms"
Wulf, Chiviacowsky, Schiller, & Avila (2010)	Soccer throw-ins (2.5 m)	Discrete	16	16	"Sneakers point at target, keep apart"; "produce 'C' at beginning of throw"; "grip with W on ball"; "ball behind you at beginning"; "propel ball forward, release in front"; "no spin on ball"; "ball released in front"; "sneaker on ground"	"Feet, hips, knees, shoulders aimed at target"; "back should be arched"; "grip should be 'W' with thumbs"; "ball start behind head at beginning"; "arm go over head when throwing"; "no spin on ball"; "ball released in front of head"; "feet remain on ground"
Wulf, Dufek, Lozano, & Pettigrew (2010)	Jump and reach	Discrete	8	8	"Concentrate on the rungs"	"Concentrate on the tips of their fingers"
Wulf, Lauterbach, &	Golf chip shot	Discrete	11	11	"Let club perform like pendulum"; "concentrate on weight of club head";	"Put hands together in correct grip"; "swing

Toole (1999)					"let club swing freely, focus on straight-line direction and acceleration moving toward bottom of the arc"	arms back and forth"; "left arm being straight, right arm being somewhat bent during backswing"; "right arm straight, left arm bent during follow-through"
Wulf, McNevin, & Shea (2001)	Stabilometer	Continuous	14	14	"Focus on the markers" attached to the platform that were placed at a distance of about 22 cm from the participant's feet	"Focus their attention on their feet and to try to keep them horizontal"
Wulf, Tollner, & Shea (2007, experiment 1)	Balancing task	Continuous	18*	18*	"Focus on the rectangles on which they stood, and to try to put an equal amount of pressure on each rectangle" [SOLID TRIALS] or to "move the rectangles as little as possible" [FOAM TRIALS]	"Focus on their feet, and to try to put an equal amount of pressure on each foot" [SOLID TRIAL], or to "move their feet as little as possible" [FOAM TRIALS]
Wulf, Tollner, & Shea (2007, experiment 2)	Balancing task	Continuous	24*	24*	"Focus on moving the disk as little as possible"	"Focus on moving their feet as little as possible"
Zachry, Wulf, Mercer, Bezodis (2005)	Free-throw shooting	Discrete	14*	14*	"Concentrate on the center of the rear of the basketball hoop"	"Concentrate on the 'snapping' motion of their wrist during the follow-through of the free throw shot"
Zentgraf, Lorey, Bischoff, Zimmermann, Stark, & Munzert (2009)	Finger movement sequence task	Discrete	15	16	"Concentrate on the keys that need to be pressed in the sequence"	"Concentrate on your moving fingers when you press the sequence"
Zimmerman, Bischoff, Lorey, Stark, Munzert, &	Finger movement sequence task	Discrete	15	16	"Concentrate on the keys of the response box"	"Concentrate on fingers"

Zentgraf (2012)

Note: Asterisk is indicative of sample size in paired groups. Multiple sample sizes within each focus group represent independent subgroup sample sizes.

Table 2. **Included studies descriptive characteristics II.**

Study	Task	Experimental Phase(s)	Independent Subgroups within study	Comparison within Study	Outcomes within Study	Effect Size Computation Method
Bell & Hardy (2009)	Golf chip shot (20 m)	Acquisition	Anxiety, neutral	Internal focus and proximal & distal external focus	Distance from target score - score of 3 if 3m short or long from the target; outside scoring area: max score of 5	Independent groups: means and standard deviations
Castaneda & Gray (2007)	Baseball batting simulation	Acquisition	Experts, novices	-	Mean temporal swing error (msec)	Paired groups: means and t-value
Chiviacowsky, Wulf, & Avila (2013)	Bean bag toss (2 m)	Acquisition, retention, transfer	-	-	Mean accuracy score (e.g. bull's eye 100)	Independent groups: means and standard deviations
Chiviacowsky, Wulf, & Wally (2010)	Stabilometer	Acquisition, retention	-	-	Time in balance (sec)	Independent groups: sample size and t-value
Chow, Woo, & Koh (2014)	Running (1 min)	Acquisition, retention	-	-	Gait cycle time (sec), stride length (m)	Independent groups pre, post-test: means and standard deviations in each group
Christina & Alpenfels (2014, experiment 1)	Golf swing with 6-iron club	Acquisition	-	-	Swing path (degrees)	Independent groups pre, post-test: means and standard deviations in each group

Christina & Alpenfels (2014, experiment 2)	Golf swing with driver club	Acquisition	-	-	Swing path (degrees)	Independent groups pre, post-test: means and standard deviations in each group
Gokeler, Benjaminse, Welling, Alferink, Eppinga & Otten (2014)	Single leg hop	Acquisition	-	Injured and non-injured leg	Jump distance (m)	Independent groups: means and standard deviations
Jackson & Holmes (2011)	Stabilometer	Acquisition, retention, transfer	Board & feet task objective	-	Root mean square error (RMSE) (degrees), time in centre (sec)	Independent groups: means and standard deviations
Jarus, Ghanouni, Abl, Fomenoff, Lundberg, Davidson, Caswell, Bickerton, & Zwicker (2015)	Manual cursor tracking via joystick	Acquisition, retention, transfer	Developmental coordination disorder children, typical developing children	-	Root mean square error (RMSE) from prescribed path (cm)	Independent groups: means and standard deviations
Kal, van der Kamp & Houdijk (2013)	Continuous leg extension/flexion, (cognitive letter fluency task among dual-task comparison)	Acquisition	-	Single & dual task, single & dominant leg	Dimensionless jerk, movement duration (sec), sample entropy (sEn)	Paired groups: means and t-value
Kalkhoran, & Shariati (2014)	Basketball dribbling task	Transfer	Dominant hand training to non-dominant hand transfer; non-dominant hand training to dominant hand transfer	-	Movement time (sec)	Independent groups pre, post-test: means and standard deviations in each group

Kasper, Elliott & Giesbrecht (2012)	Golf putt (1.37 m, 1.50 m)	Acquisition	-	-	Average distance from target (cm)	Independent groups: sample size and t-value
Keller, Lauber, Gottschalk & Tabue (2014)	Jump height	Acquisition	-	-	Jump height (cm)	Paired groups: means and t-value
Klostermann, Kredal & Hossner (2014)	Golf putting (3 m)	Acquisition	Expert, novice	-	Quiet eye offset (msec), quiet eye onset (msec), radial error (mm)	Paired groups: means and t-value
Kukar, Zia, Sehgal, & Khushwaha (2013)	Dart throwing	Acquisition, retention, transfer	-	-	Dart throwing; mean radial error (cm)	Independent groups: means and standard deviation
Land, Frank & Schack (2014)	Golf putting (3 m)	Retention	-	2, 2.75, 3.5, 4.25, & 5 m distances	Bivariate radial error (cm), mean radial error (cm)	Independent groups: means and standard deviations
Land, Tenenbaum, Ward & Marquardt (2013)	Golf putting (3 m)	Acquisition	-	-	Number of made putts	Independent groups: means and standard deviations
Landers, Wulf, Wallman, & Guadagnoli (2005)	Stabilometer	Acquisition	Fallers only	Eyes-open, eyes-closed, & sway-referenced	Stabilometer: balance equilibrium score (0-100)	Paired groups: means and t-value
Laufer, Rotem-Leher, Ronen, Khayutin & Rozenburg (2007)	Stabilometer	Acquisition, retention	-	Level 4, level 6	Anterior/posterior stability index, medial/lateral stability index, overall stability index	Paired groups: means and t-value
Lidor, Ziv, & Tenenbaum (2013)	Ball throwing (3.3 m)	Acquisition	-	Auditory, quiet, and visual distraction	Variable error (m), absolute error (m)	Independent groups: means and standard deviations
Lohse (2012)	Isometric force production: plantar flexion (25%, 50% MVC)	Acquisition, retention, transfer	-	-	Absolute error of force applied (% MVC), pre-movement time (sec)	Independent groups: means and t-value

Lohse & Sherwood (2011, experiment 1)	Wall-sit	Acquisition	-	-	Trial duration (time to failure) (sec)	Paired groups: means and t-value
Lohse & Sherwood (2011, experiment 2)	Wall-sit	Acquisition	-	Zero, External & internal good biases	Trial duration (time to failure) (sec)	Paired groups: means and t-value
Lohse, Sherwood, & Healy (2010)	Dart throwing	Acquisition	-	-	Absolute error (cm)	Paired groups: means and t-value
Lohse, Sherwood, & Healy (2011)	Isometric force production: plantar flexion (30% MVC)	Acquisition	-	-	Absolute error of force applied (% MVC)	Paired groups: means and t-value
Lohse, Sherwood, & Healy (2014, experiment 1)	Dart throwing (2.37 m)	Acquisition, transfer	-	-	Bivariate variable error (cm), mean radial error (cm)	Independent groups: means and standard deviations
Lohse, Sherwood, & Healy (2014, experiment 2)	Dart Throwing (2.37 m)	Acquisition	-	-	Bivariate variable error (cm), mean radial error (cm)	Independent groups: means and standard deviations
Makaruk, Porter, Czaplicki, Sadowki, & Sacewicz (2012)	Counter-movement jump, drop-jump, standing long-jump	Acquisition, retention	-	Counter-movement jump, drop-jump, standing long-jump	Counter-movement jump: difference of force (N), difference of height (m), difference of knee flexion (degrees); drop-jump: difference of contact time (sec), difference of force (N), difference of height (m), difference of knee flexion (degrees); standing long-jump: difference of distance (m)	Paired Groups: means and standard deviations
Makaruk, Porter, & Makaruk (2013)	Shot-put	Acquisition	-	Overhead throw, underhand throw	Throwing distance (m)	Independent groups: mean differences and standard deviations of difference in each group

Marchant, Clough, Crawshaw, & Levy (2009)	Dart throwing (3.66 m)	Acquisition	-	Session two	Mean absolute error (cm), number of bull's eye	Independent groups: means and standard deviations
Marchant, Greig, & Scott (2009)	Single elbow flexion	Acquisition	-	-	Integrated EMG & torque (% MVC), peak EMG & torque (% MVC)	Paired groups: sample size and t-value
Marchant, Grieg, Bullough & Hitchen (2011)	Assisted bench press, bench press, free squat	Acquisition	-	Assisted bench press, bench press, free squat	Maximum repetitions to failure	Paired groups: means and t-value
Maurer & Munzert (2013, experiment 1)	Free throw shooting	Acquisition	Familiar and unfamiliar cues	-	Percentage of free-throw shots made (%)	Paired groups: means and t-value
Maurer & Munzert (2013, experiment 2)	Golf putting (3 m)	Acquisition	Familiar and unfamiliar cues	-	Percentage of putts made (%)	Paired groups: means and t-value
Munzert, Maurer, & Reiser (2014)	Golf putting (4.50 m)	Retention	-	-	Absolute error (cm)	Cohen's *d*, variance
McNevin, Weir, & Quinn (2013)	Postural and supra-postural task (manual tracking)	Acquisition	Young & old adults	0.5 & 1.0 Hz	Anterior/posterior mean power frequency (MPF) (Hz), medial/lateral mean power frequency (MPF) (Hz), postural sway (anterior/posterior) (m), postural sway (medial/lateral) (m), time on contact (sec)	Paired groups: means and t-value
Mullen, Faull, Jones, & Kingston (2012)	Driving simulation	Retention	-	Neutral, anxiety (in retention)	Lap time (sec), number of driving errors	Independent groups: means and standard deviations
Neumann & Brown (2013)	Sit-ups	Acquisition	-	-	Degrees of movement (degrees), heart rate (beats/min), mean EMG activity (uV)	Paired groups: means and t-value
Polskaia, Richer, Dionne, & Lajoie (2015)	Stabilometer	Acquisition	-	-	Standard deviation of centre of pressure (COP): anterior-posterior direction (cm); standard	Paired groups: means and t-value

					deviation of centre of pressure (COP): medial-lateral direction (cm); area of 95% confidence ellipse (cm^2	
Porter, Ostrowski, Nolan, & Wu (2010)	Standing long jump	Acquisition	-	-	Jumping distance (cm)	Independent groups: means and standard deviations
Rotem-Lehrer & Laufer (2007)	Balance training	Acquisition, retention	-	-	Anterior/posterior stability index (degrees), medial/lateral stability index (degrees), overall stability index (degrees)	Independent groups: pre, post means and standard deviations
Saemi, Porter, Wulf, Ghotbi-Varzaneh, & Bakhtiari (2013)	Throwing task (3 m)	Acquisition, retention	-	-	Throwing score (e.g. score of 10 for centre target hit)	Independent groups: means and standard deviation
Shafizadeh, Platt, & Bahram (2013)	Dart throwing (2 m)	Acquisition, retention, transfer	Observation practice, physical practice (retention & transfer only)	-	Dart score (e.g. score of 100 for bull's-eye hit)	Independent groups: means and standard deviations
Shea & Wulf (1999)	Stabilometer	Acquisition, retention	No feedback, feedback	-	Root mean square error (RMSE) (degrees)	Independent groups: means and standard deviations
Sulewski, Tripp, & Wikstrom (2012)	Balance training	Acquisition, retention	-	-	Anterior/posterior stability index (degrees), medial/lateral stability index (degrees), overall stability index (degrees)	Independent groups: mean differences and standard deviations of difference in each group
Vance, Wulf, McNevin, Tollner & Mercer (2004, experiment 1)	Elbow flexion/extension	Acquisition	-	-	Extension angular velocity (deg/sec), flexion angular velocity (deg/sec), range of motion (degrees), total angular velocity (deg/sec)	Paired groups: sample size and t-value

Wulf & Dukek (2009)	Jump and reach	Acquisition	-	-	Centre of displacement (cm), impulse (Ns), jump height (cm)	Paired groups: means and t-value
Wulf & Su (2007, experiment 1)	Golf chip shot (15 m)	Acquisition, retention	-	-	Chip score (e.g. 5 for centre target hit)	Independent groups: means and standard deviations
Wulf, Chiviacowsky, Schiller, & Avila (2010)	Soccer throw-ins (2.5 m)	Acquisition, retention, transfer	100% feedback frequency, 33% feedback frequency	-	Throw-in score (e.g. 5 for centre target hit)	Independent groups: means and standard deviations
Wulf, Dufek, Lozano, & Pettigrew (2010)	Jump and reach	Acquisition	-	-	Jump height (cm)	Paired groups: means and t-value
Wulf, Lauterbach, & Toole (1999)	Golf chip shot (15 m)	Acquisition, retention	-	-	Chip score	Independent groups: sample sizes and t-value
Wulf, McNevin, & Shea (2001)	Stabilometer	Acquisition, retention	-	-	Probe reaction time (sec)	Independent groups: means and standard deviations
Wulf, Tollner, & Shea (2007, experiment 1)	Balancing task	Acquisition	-	Foam, solid trials	Root mean square error (RMSE) of centre of pressure vector	Paired groups: means and t-value
Wulf, Tollner, & Shea (2007, experiment 2)	Balancing task	Acquisition	-	One leg, two leg trials	Root mean square error (RMSE) of centre of pressure vector	Paired groups: sample size and t-value
Zachry, Wulf, Mercer, Bezodis (2005)	Free-throw shooting	Acquisition	-	-	Shot score (e.g. 5 for made basket)	Paired groups: means and t-value
Zentgraf, Lorey, Bischoff, Zimmermann, Stark, & Munzert (2009)	Finger movement sequence task	Acquisition	-	-	Mean sequence duration (sec)	Independent groups: means and standard deviations

Zimmerman, Bischoff, Lorey, Stark, Munzert, & Zentgraf (2012)	Finger movement sequence task	Acquisition	-	-	Mean sequence duration (sec), mean number of errors	Independent groups: means and standard deviations

5.2 Syntheses of Results

The meta-analysis conducted on the acquisition phase yielded a point estimate of the overall summary effect of 0.409. This indicated that the attentional focus effect was responsible for a shift in the immediate performance of 0.409 standard deviations to the right of the population mean. This observed estimate was greater than zero, z = 7.047, p = .000. Moreover, heterogeneity was found, I^2 = 59.984; Q = 157.437, df = 63, p = .000. This indicated that approximately 60% of the observed variance of individual study effect from the overall summary effect reflected true difference in effect sizes between studies. For the retention phase, a point estimate of the overall summary effect of 0.569 was obtained. This indicated that the attentional focus effect was responsible for a shift in the immediate performance of 0.569 standard deviations to the right of the population mean. This observed estimate was greater than zero, z = 6.757, p = .000. Moreover, no heterogeneity was found within the retention phase, I^2 = 12.603; Q = 30.894, df = 27, p = .270. For the transfer phase, a point estimate of the overall summary effect of 0.556 was obtained. This indicated that the attentional focus effect was responsible for a shift in the immediate performance of 0.556 standard deviations to the right of the population mean. This observed estimate was greater than zero, z = 3.384, p = .001. Moreover, heterogeneity was found, I^2 = 58.815; Q = 33.993, df = 14, p = .002. This indicated that approximately 59% of the observed variance of individual study effect from the overall summary effect reflected true difference in effect sizes between studies.

Table 3. **Summary of syntheses of results.**

Experimental Phase	Number of observations	Point Estimate	Standard Error	Variance	Lower Limit CI	Upper Limit CI
Acquisition	64	0.409	0.058	0.003	0.295	0.522
Retention	28	0.569	0.084	0.007	0.404	0.733
Transfer	15	0.556	0.165	0.027	0.233	0.879

Table 4. **Synthesis of results: Acquisition Phase.**

Study Number	Authors	Subgroup	Hedge's *g*	Lower 95% Confidence Interval	Lower 95% Confidence Interval	Relative Study Weight
65	Bell & Hardy (2009)	Anxiety	2.857	1.663	4.052	0.686
64	Bell & Hardy (2009)	Neutral	2.093	1.052	3.134	0.847
63	Castaneda & Gray (2007)	Experts	1.006	0.217	1.794	1.238
62	Castaneda & Gray (2007)	Novices	0.094	-0.523	0.712	1.632
61	Chiviacowsky et al. (2013)	N/A	0.231	-0.547	1.009	1.260
60	Chiviacowsky et al. (2010)	N/A	0.449	-0.235	1.134	1.464
59	Chow, et al. (2014)	N/A	-0.115	-1.042	0.813	0.999
58	Christina & Alpenfels (2014, experiment 1)	N/A	0.688	-0.030	1.406	1.387
57	Christina & Alpenfels (2014, experiment 2)	N/A	0.525	-0.233	1.283	1.300
56	Gokeler et al. (2014)	N/A	-0.081	-1.014	0.851	0.992
55	Jackson & Holmes (2011)	Board Task Objective	0.555	-0.347	1.458	1.038
54	Jackson & Holmes (2011)	Feet Task Objective	-0.123	-1.007	0.761	1.068
53	Jarus et al. (2015)	Developmental Coordination Disorder Children	0.264	-0.807	1.334	0.812
52	Jarus et al. (2015)	Typically Developing Children	0.154	-0.863	1.171	0.877
51	Kukar et al. (2013)	N/A	0.610	-0.189	1.409	1.219
50	Kal et al. (2013)	N/A	0.360	-0.003	0.722	2.438
49	Kasper et al. (2012)	N/A	-0.081	-0.840	0.678	1.298
48	Keller et al. (2014)	N/A	0.010	-0.421	0.441	2.203
47	Klostermann et al. (2014)	Expert	0.092	-0.480	0.664	1.759
46	Klostermann et al. (2014)	Novice	0.439	-0.117	0.994	1.806
45	Land et al. (2013)	N/A	1.092	0.187	1.997	1.034
44	Landers et al. (2005)	Fallers	0.287	-0.315	0.890	1.673
43	Laufer et al. (2007)	N/A	0.656	0.026	1.285	1.601
42	Lidor et al. (2013)	N/A	0.911	0.318	1.504	1.700
41	Lohse (2012)	N/A	0.472	-0.313	1.256	1.247
40	Lohse & Sherwood (2011, experiment 1)	N/A	0.344	0.031	0.657	2.610
39	Lohse & Sherwood (2011, experiment 2)	N/A	0.251	-0.201	0.703	2.132
38	Lohse et al. (2010)	N/A	0.616	0.035	1.197	1.732

37	Lohse et al. (2011)	N/A	0.651	0.063	1.238	1.716
36	Lohse et al. (2014, experiment 1)	N/A	0.099	-0.509	0.707	1.658
35	Lohse et al. (2014, experiment 2)	N/A	0.550	-0.070	1.169	1.628
34	Makaruk et al. (2013)	N/A	0.258	0.171	0.345	3.227
33	Marchant et al. (2009)	N/A	1.195	0.695	1.695	1.976
32	Marchant et al. (2009)	N/A	0.559	0.148	0.971	2.267
31	Marchant et al. (2011)	N/A	0.872	0.353	1.391	1.916
30	Maurer & Munzert (2013, experiment 1)	Familiar Cues	-0.200	-0.599	0.199	2.312
29	Maurer & Munzert (2013, experiment 1)	Unfamiliar Cues	-0.161	-0.558	0.236	2.317
28	Maurer & Munzert (2013, experiment 2)	Familiar Cues	-0.031	-0.524	0.462	1.997
27	Maurer & Munzert (2013, experiment 2)	Unfamiliar Cues	-0.340	-0.848	0.169	1.948
26	McNevin et al. (2013)	Older	0.004	-0.538	0.547	1.844
25	McNevin et al. (2013)	Younger	0.025	-0.513	0.563	1.859
24	Neumann & Brown (2013)	N/A	2.238	1.282	3.194	0.958
23	Polskaia et al. (2015)	N/A	0.048	-0.373	0.470	2.233
22	Porter et al. (2010)	N/A	0.239	-0.118	0.595	2.458
21	Rotem-Lehrer & Laufer (2007)	N/A	0.770	0.102	1.438	1.504
20	Saemi et al. (2013)	N/A	0.941	0.051	1.831	1.058
19	Shafizadeh et al. (2013)	N/A	0.241	-0.536	1.019	1.261
18	Shea & Wulf (1999)	Feedback	0.355	-0.584	1.295	0.982
17	Shea & Wulf (1999)	No Feedback	-0.126	-1.056	0.803	0.997
16	Sulewski et al. (2012)	N/A	0.188	-0.743	1.119	0.994
15	Vance et al. (2004, experiment 1)	N/A	0.607	0.005	1.208	1.675
14	Wulf & Dukek (2009)	N/A	0.714	0.066	1.361	1.555
13	Wulf, Dufek, et al. (2010)	N/A	0.793	0.064	1.521	1.364
12	Wulf, Chiviacowsky et al. (2010)	100 % Feedback Frequency	-0.235	-0.913	0.443	1.480
11	Wulf, Chiviacowsky et al., (2010)	33 % Feedback Frequency	0.134	-0.542	0.811	1.484

10	Wulf et al. (1999)	N/A	2.510	1.417	3.604	0.786
9	Wulf et al. (2001)	N/A	1.774	0.918	2.631	1.114
8	Wulf & Su (2007, experiment 1)	N/A	0.177	-0.665	1.020	1.138
7	Wulf et al. (2007, experiment 1)	N/A	-0.034	-0.482	0.413	2.147
6	Wulf et al. (2007, experiment 2)	N/A	0.229	-0.222	0.680	2.134
5	Zachry et al. (2005)	N/A	0.448	-0.072	0.968	1.913
4	Zentgraf et al. (2009)	N/A	-0.053	-0.739	0.633	1.460
3	Makaruk et al. (2012)	N/A	1.168	0.321	2.015	1.131
2	Zimmerman et al. (2012)	N/A	0.169	-0.519	0.857	1.456
1	**Overall Summary Effect**	**N/A**	**0.406**	**0.295**	**0.517**	**100.000**

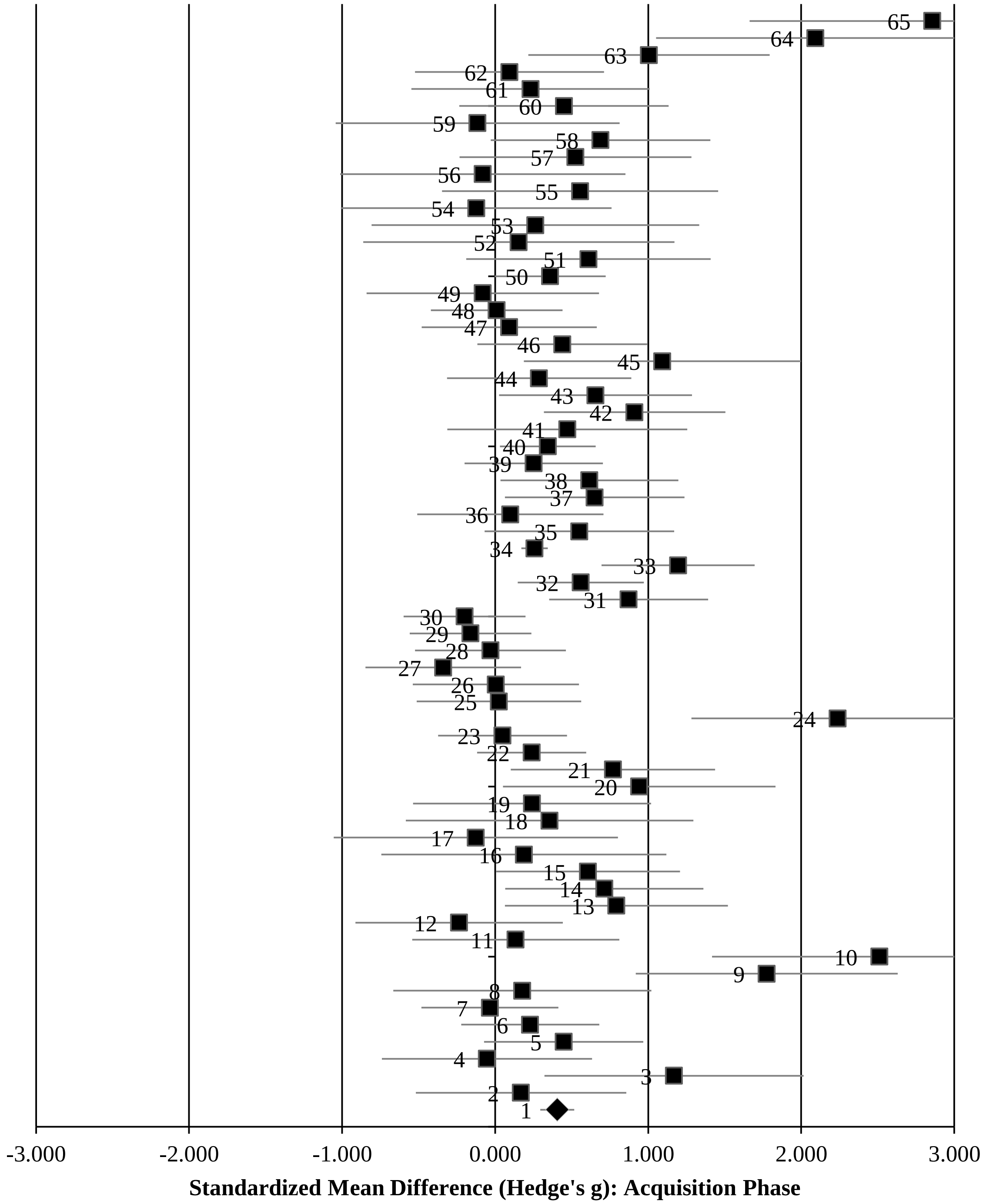

Figure 3. Synthesis of results: Acquisition phase forest plot.

Table 5: <u>Synthesis of results: Retention Phase</u>

Study Number	Authors	Subgroup	Hedge's *g*	Lower 95% Confidence Interval	Lower 95% Confidence Interval	Relative Study Weight
29	Chiviacowsky et al. (2013)	N/A	0.610	-0.184	1.404	3.732
28	Chiviacowsky et al. (2010)	N/A	0.734	0.035	1.433	4.641
27	Chow, et al. (2014)	N/A	-0.115	-1.042	0.813	2.835
26	Christina & Alpenfels, (2014, experiment 1)	N/A	0.732	0.011	1.452	4.410
25	Christina & Alpenfels (2014, experiment 2	N/A	0.692	-0.077	1.461	3.945
24	Jackson & Holmes (2011)	board task objective	0.563	-0.338	1.464	2.986
23	Jackson & Holmes (2011)	feet task objective	-0.226	-1.109	0.658	3.095
22	Jarus et al. (2015)	Developmental coordination disorder children	-0.085	-1.145	0.975	2.223
21	Jarus et al. (2015)	Typically developing children	-0.181	-1.197	0.836	2.400
20	Kukar et al. (2013)	N/A	0.891	0.078	1.704	3.584
19	Land et al. (2014)	N/A	0.988	0.093	1.883	3.023
18	Laufer et al. (2007)	N/A	0.196	-0.414	0.806	5.803
17	Lohse (2012)	N/A	1.258	0.406	2.110	3.300
16	Makaruk et al. (2013)	N/A	1.168	0.321	2.015	2.669
15	Mullen et al. (2012)	N/A	0.532	-0.428	1.491	4.351
14	Munzert et al. (2014)	N/A	0.817	0.091	1.544	5.008
13	Rotem-Lehrer & Laufer (2007)	N/A	0.770	0.102	1.438	3.319
12	Saemi et al. (2013)	N/A	0.413	-0.436	1.262	3.827
11	Shafizadeh et al. (2013)	Observation	0.446	-0.336	1.229	3.789
10	Shafizadeh et al. (2013)	Physical practice	0.536	-0.251	1.324	2.683
9	Shea & Wulf (1999)	N/A	0.589	-0.367	1.545	2.819
8	Shea & Wulf (1999)	N/A	0.240	-0.690	1.171	2.814
7	Sulewski et al. (2012)	N/A	0.188	-0.743	1.119	4.854
6	Wulf & Su (2007, experiment 1)	N/A	0.337	-0.344	1.017	4.907
5	Wulf, Chiviacowsky et al. (2010)	100% feedback frequency	-0.109	-0.785	0.567	3.231
4	Wulf, Chiviacowsky et al.	33% feedback frequency	1.054	0.192	1.916	3.450

	(2010)					
3	Wulf et al. (1999)	N/A	1.550	0.719	2.380	2.966
2	Wulf et al. (2001)	N/A	1.088	0.183	1.993	3.335
1	**Overall Summary Effect**	**N/A**	**0.568**	**0.404**	**0.733**	**100.000**

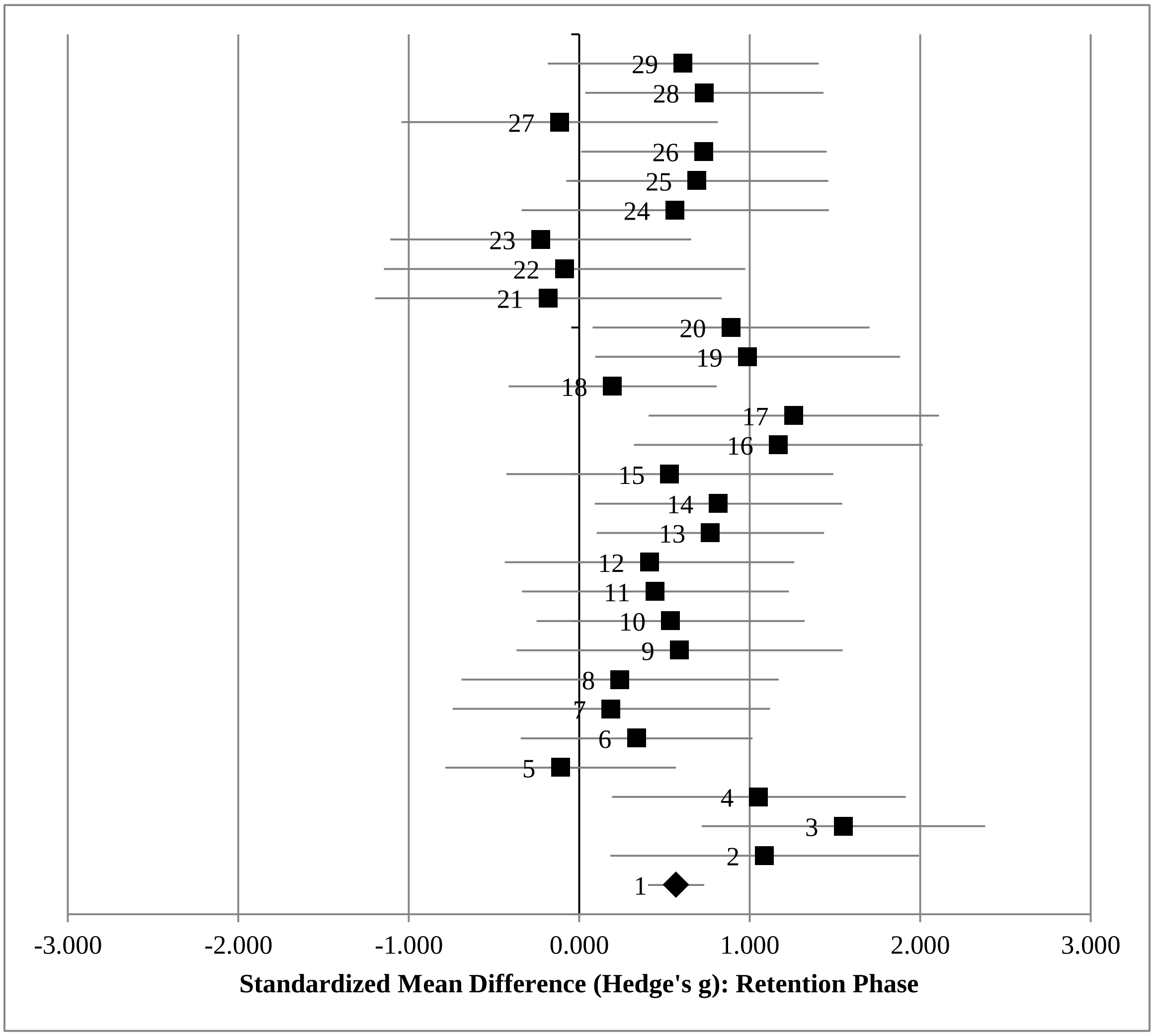

Figure 4. <u>**Synthesis of results: Retention phase forest plot.**</u>

Table 6: **Synthesis of results: Transfer Phase**

Study Number	Authors	Transfer task	Subgroup	Hedge's *g*	Lower 95% Confidence Interval	Lower 95% Confidence Interval	Relative Study Weight
16	Chiviacowsky et al. (2013)	Bean bad toss at 3 m distance (versus 2 m)	N/A	0.601	-0.193	1.394	6.795
15	Jackson & Holmes (2011)	Not stated	Board task objective	0.565	-0.337	1.466	6.066
14	Jackson & Holmes (2011)	Not stated	Feet task objective	-0.248	-1.132	0.636	6.180
13	Jarus et al. (2015)	Vertical tracking target (versus horizontal tracking target)	Developmental coordination disorder children	-0.002	-1.061	1.058	5.137
12	Jarus et al. (2015)	Vertical tracking target (versus horizontal tracking target)	Typically developing children	0.467	-0.563	1.498	5.298
11	Kalkhoran, & Shariati (2014)	Basketball dribbling: training with dominant hand, testing with non-dominant hand and vice versa	Dominant hand transfer	2.832	1.833	3.831	5.474
10	Kalkhoran, & Shariati (2014)	Basketball dribbling: training with dominant hand, testing with non-dominant hand and vice versa	Non-dominant hand transfer	0.910	0.177	1.644	7.231
9	Kukar et al. (2013)	Dart throw at 4 m distance (versus 3 m)	N/A	1.244	0.395	2.093	6.412
8	Lohse (2012)	Isometric force production: plantar flexion - different target %MVC (i.e. if trained at 25 %MVC, then tested at 50 %MVC and vice versa	N/A	0.583	-0.208	1.374	6.815
7	Lohse et al. (2014 experiment 1)	Additional 1 Kg weight added to dart throwing arm	N/A	0.043	-0.565	0.650	8.195

6	Munzert et al. (2014)	Switched training focus during golf putting task (i.e. internal focus in training, external focus in testing and vice versa)	N/A	0.501	-0.207	1.209	7.421
5	Shafizadeh et al. (2013)	Dart throw at 3 m (versus 2 m)	Observation	0.310	-0.468	1.087	6.910
4	Shafizadeh et al. (2013)	Dart throw at 3 m (versus 2 m)	Physical practice	0.746	-0.055	1.547	6.744
3	Wulf et al. (2010)	Soccer throw-in at 50% of individual's pre-test distance	100% feedback frequency	0.076	-0.600	0.752	7.665
2	Wulf et al. (2010)	Soccer throw-in at 50% of individual's pre-test distance	33% feedback frequency	0.171	-0.506	0.848	7.657
1	**Overall Summary Effect**	**N/A**	**N/A**	**0.556**	**0.234**	**0.878**	**100.000**

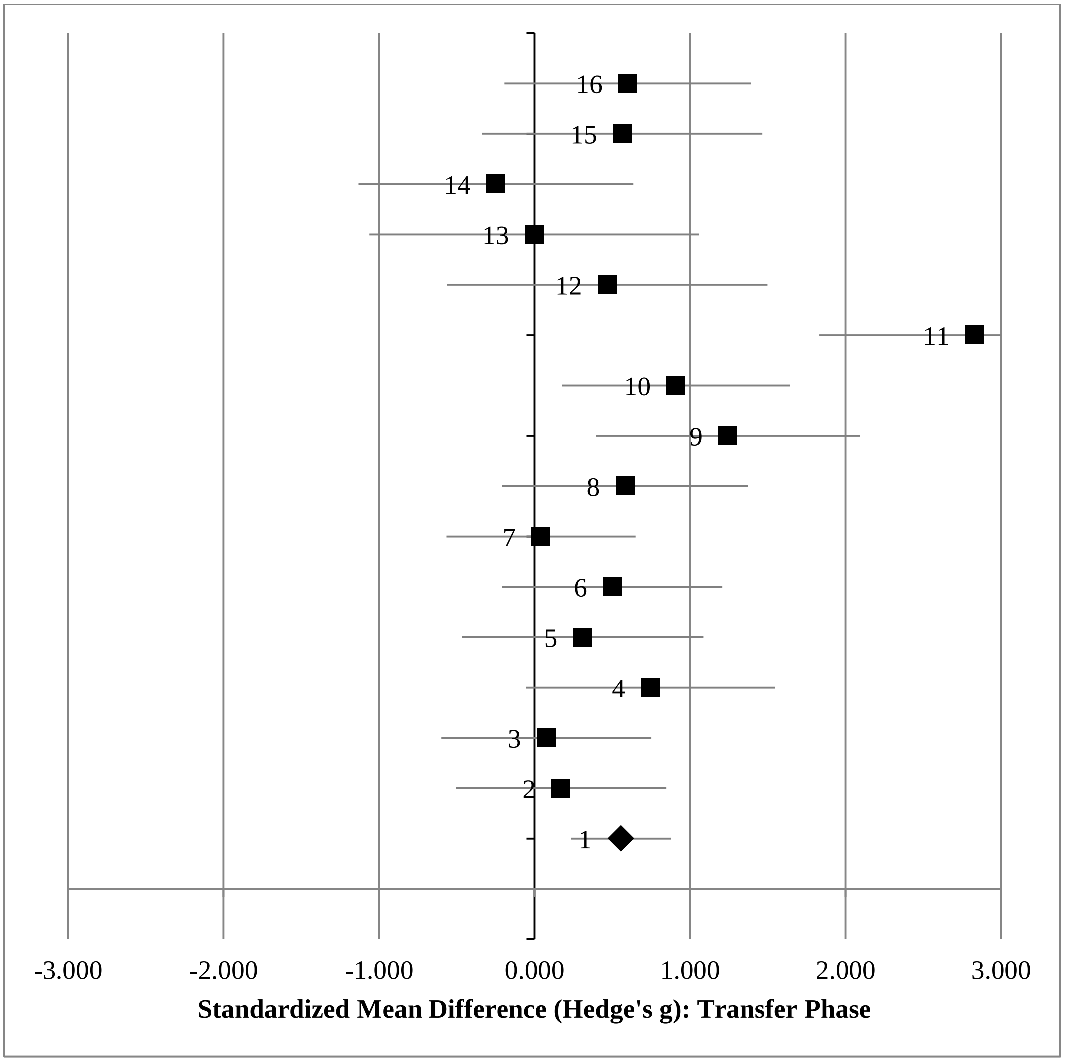

Figure 5. **<u>Synthesis of results: Transfer phase forest plot.</u>**

5.3 Reporting Bias Analyses

For the acquisition phase, Egger et al.'s Regression Intercept revealed funnel plot asymmetry, y = 0.826, p = .001 (2-tailed).

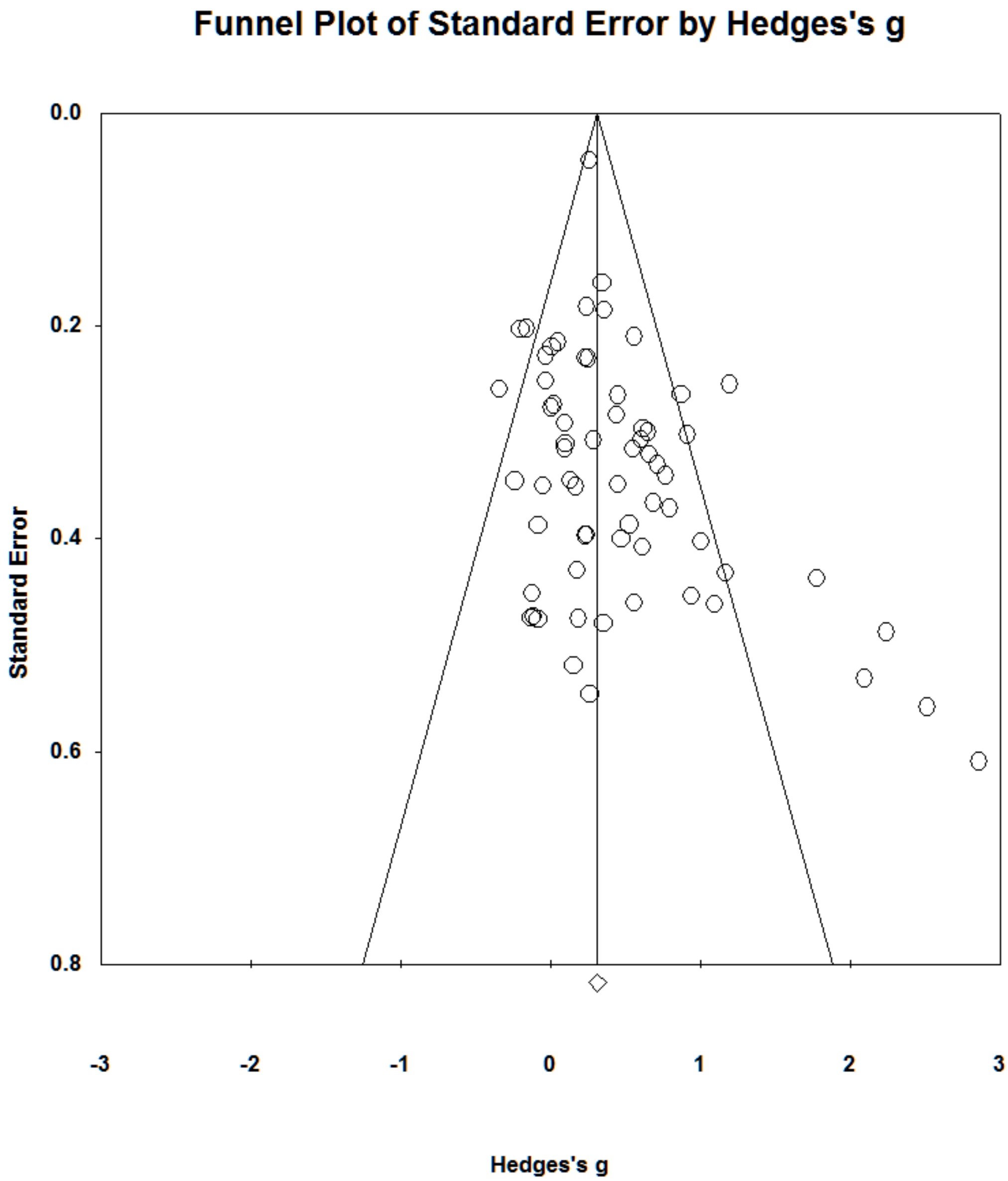

Figure 6. **Acquisition phase funnel plot.**

Rosenthal's Fail-Safe *N* yielded a significant z-value, z = 10.98, p = .000. Furthermore, it was estimated that the number of missing studies that would bring the p-value above the alpha is 1946 studies. Duval and Tweedie's Trim and Fill method yielded an estimate of the unbiased overall summary effect as 0.483 (LCI = 0.367, UCI = 0.599) with six studies trimmed (i.e. added to the right of the overall summary effect).

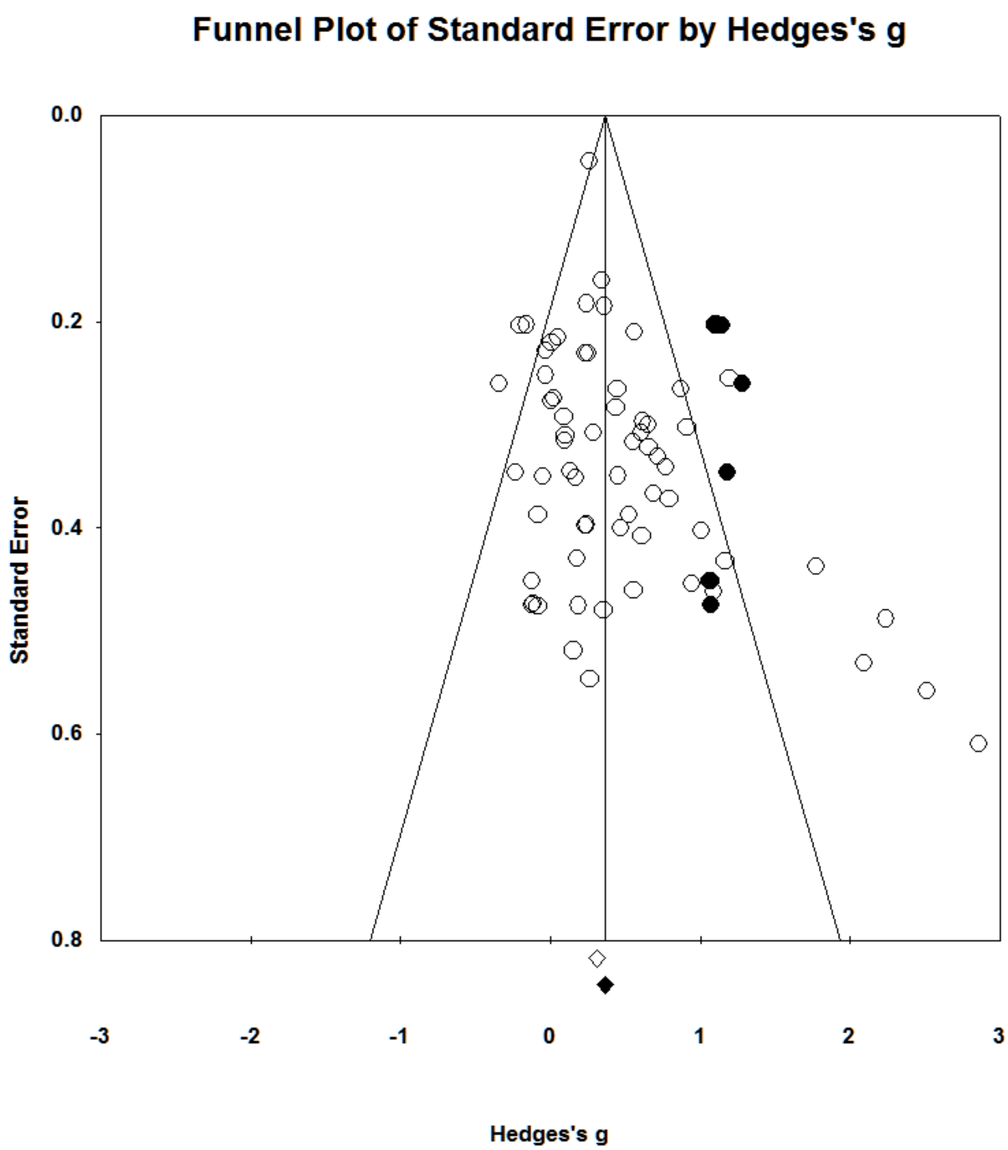

Figure 7. **Acquisition phase funnel plot with trim and fill studies imputed.**

For the retention phase, Egger et al.'s Regression Intercept revealed no funnel plot asymmetry, y = -.156, p = .918 (2-tailed).

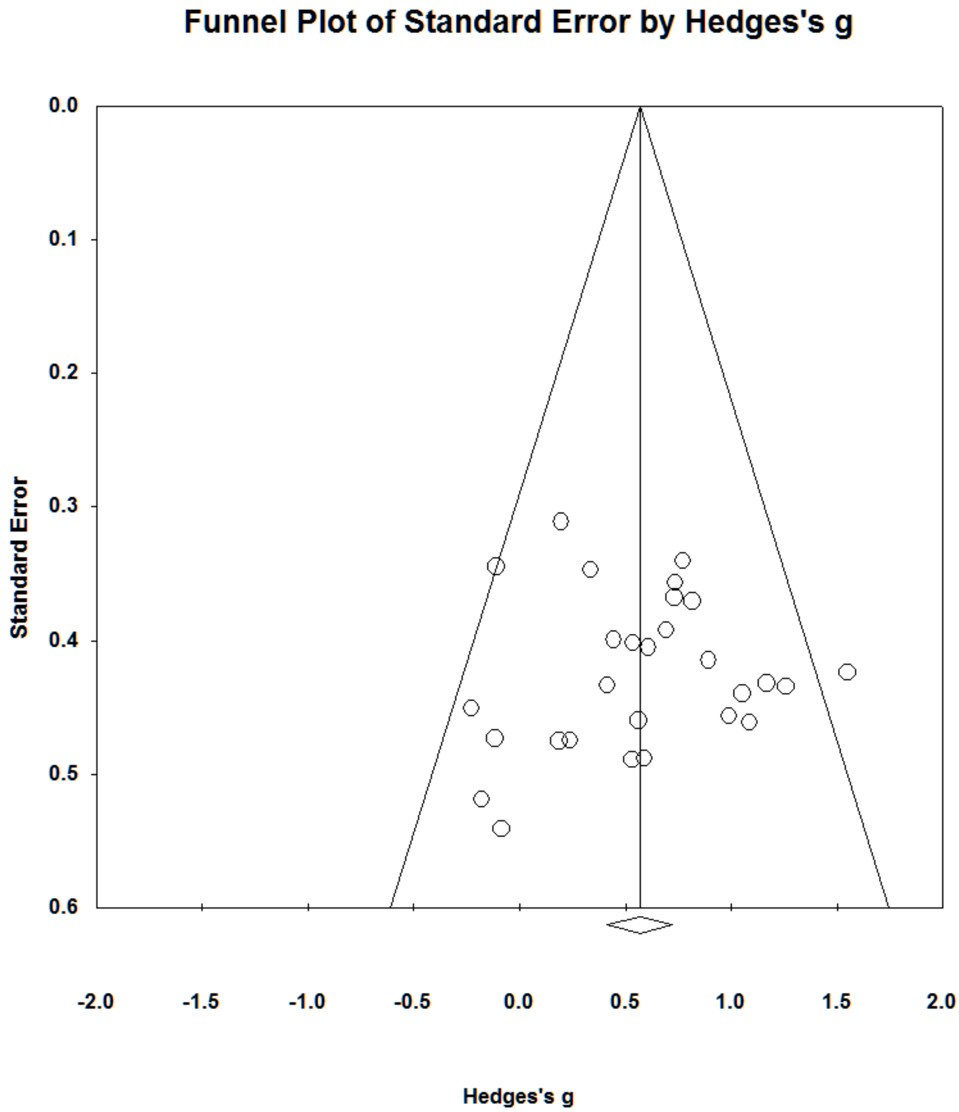

Figure 8. **<u>Retention phase funnel plot.</u>**

Rosenthal's Fail-Safe *N* yielded a significant z-value, z = 7.174, p = .000. Furthermore, it was estimated that the number of missing studies that would bring the p-value above the alpha is 348 studies. Duval and Tweedie's Trim and Fill method yielded an estimate of the unbiased overall summary effect and lower & upper confidence intervals identical to the observed effect.

For the transfer phase, Egger et al.'s Regression Intercept revealed no funnel plot asymmetry, y = 3.95, p = 0.134 (2-tailed).

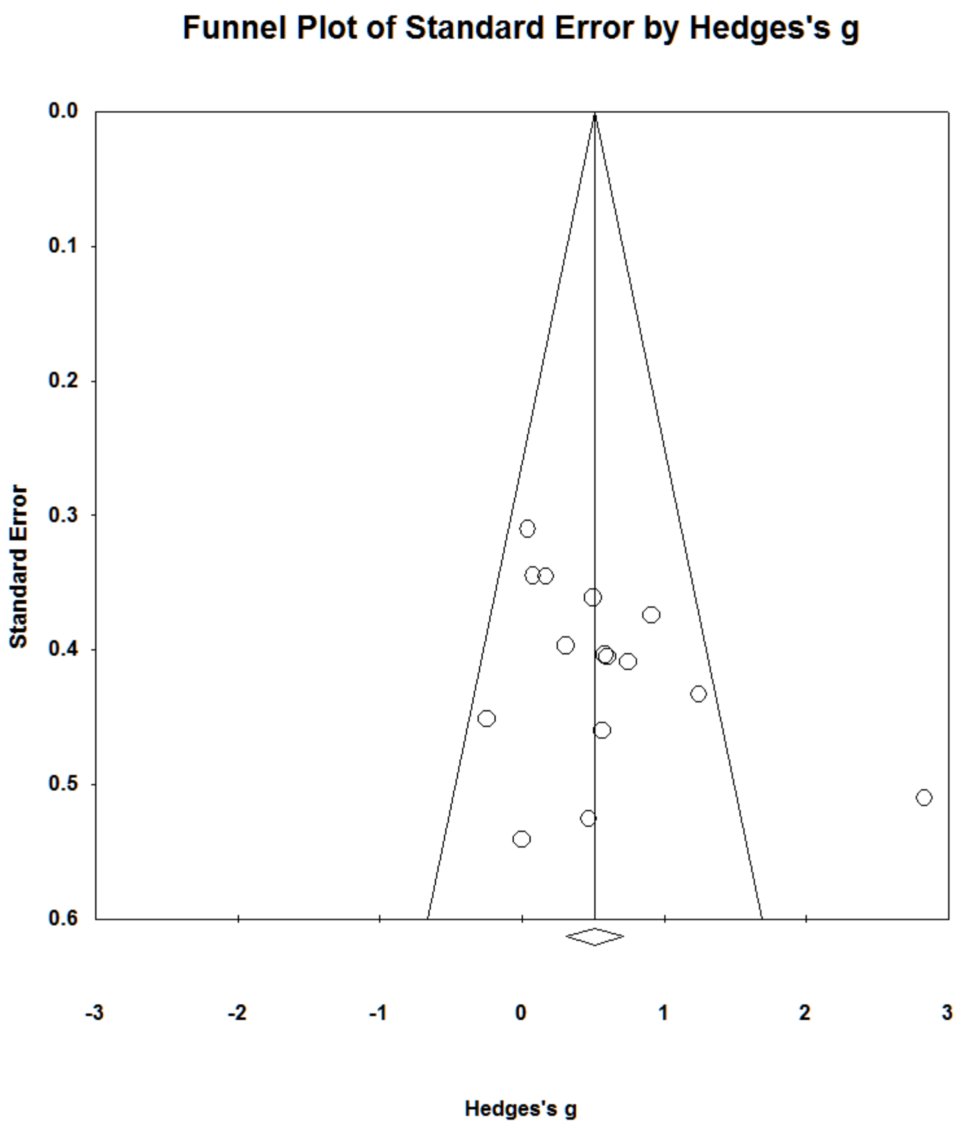

Figure 9. <u>Transfer phase funnel plot.</u>

Rosenthal's Fail-Safe *N* yielded a significant z-value, z = 5.215, p = .000. Furthermore, it was estimated that the number of missing studies that would bring the p-value above the alpha is 92 studies. Lastly, Duval and Tweedie's Trim and Fill method yielded an estimate of the unbiased overall summary effect as 0.847 (LCI = 0.515, UCI = 1.178) with five studies trimmed (i.e. added to the right of the overall summary effect).

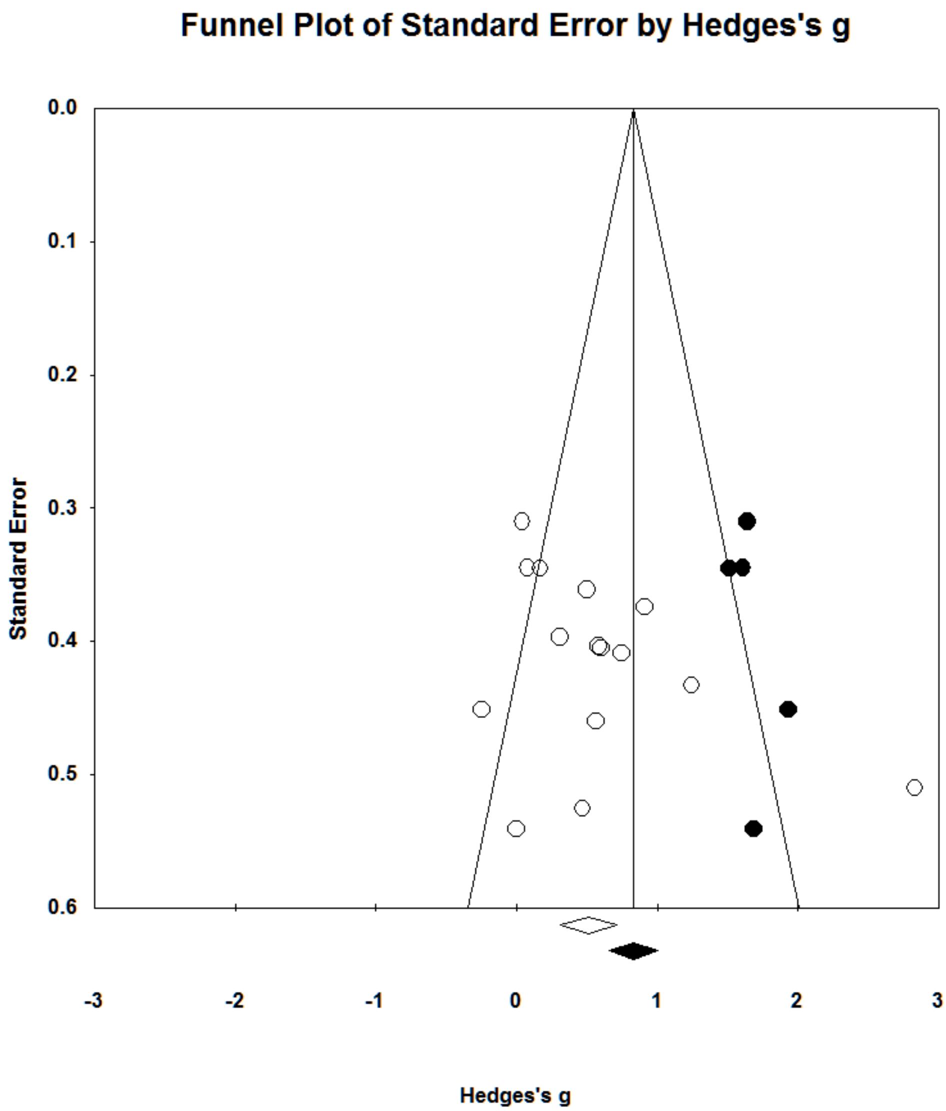

Figure 10. **<u>Transfer phase funnel plot with trim and fill studies imputed.</u>**

5.4 Subgroup Analyses

It is important to note that all of the tasks subjected to the analyses were classified as closed tasks. This is due to the fact that they were all conducted in a laboratory or task specific setting (i.e. playing field) that was controlled and predictable. Henceforth, the subgroup analyses were in the context of the discrete/continuous dimension.

To address the heterogeneity found in the acquisition phase (I^2 = 59.984), point estimates for the overall summary effect were greater than zero, z = 6.895, p = .000 and z = 2.598, p = .009, for the discrete and continuous subgroups, respectively.

Table 7. <u>Summary of acquisition phase subgroup analysis.</u>

Task Dimension	Number of observations	Point Estimate	Standard Error	Variance	Lower Limit CI	Upper Limit CI
Discrete	40	0.505	0.073	0.005	0.361	0.648
Continuous	24	0.247	0.095	0.009	0.061	0.522

Within each subgroup, heterogeneity was present in the discrete subgroup, Q = 141.825, df = 39, p = 0.000, I^2 = 72.501; and not present in the continuous subgroup, Q = 14.212, df = 23, p = 0.921, I^2 = 0.00. More importantly, heterogeneity was present between discrete and continuous subgroups, Q = 4.649, df = 1, p = 0.031. This meant that the subgroups were related to the overall summary effect. Attempts to explain the proportion of variance explained by subgroup variance yielded an R^2 value < 0.0 (i.e. $R^2 = 1 - [0.106/0.098] = -0.082$).

Although heterogeneity was not found in the retention phase, subgroup analysis was conducted to allow for speculations of the trends observed. Point estimates for the overall summary effect within both subgroups were greater than zero, z = 5.477, p =.000 and z = 4.085, p =.000, for the discrete and continuous task dimensions, respectively.

Table 8. **Summary of retention phase subgroup analysis.**

Task Dimension	Number of observations	Point Estimate	Standard Error	Variance	Lower Limit CI	Upper Limit CI
Discrete	13	0.655	0.120	0.014	0.420	0.889
Continuous	15	0.484	0.118	0.014	0.252	0.716

Within each subgroup, no heterogeneity was present in both the discrete and continuous subgroups, Q = 10.635, df = 12, p = 0.560, I^2 = 0.00 and Q = 19.209, df = 14, p = 0.157, I^2 = 27.119, respectively. More importantly, no heterogeneity was present between discrete and continuous subgroups, Q = 1.032, df = 1, p = 0.310. Attempts to explain the proportion of variance explained by subgroup variance were not warranted.

To address the heterogeneity found in transfer phase (I^2 = 58.815), point estimates for the overall summary effect within both subgroups were greater than zero, z = 2.010, p =.044 and z = 2.841, p =.005, for the discrete and continuous task dimensions, respectively.

Table 9. **Summary of Transfer phase subgroup analysis.**

Task Dimension	Number of observations	Point Estimate	Standard Error	Variance	Lower Limit CI	Upper Limit CI
Discrete	8	0.436	0.217	0.047	0.011	0.861
Continuous	7	0.721	0.254	0.064	0.223	1.218

Within each subgroup, no heterogeneity was present in the discrete subgroup, Q = 7.539, df = 7, p = 0.375, I^2 = 7.149; and was present in the continuous subgroup, Q = 24.265, df = 6, p = 0.000, I^2 = 75.273. More importantly, no heterogeneity was present between discrete and continuous subgroups, $Q = 0.728$, $df = 1$, $p = 0.394$. Attempts to explain the proportion of variance explained by subgroup variance were not warranted.

CHAPTER 6

DISCUSSION

Before interpreting the results of the syntheses and subsequent subgroup analyses, it is important to initially interpret the results of the reporting bias analyses. Recall that the reporting bias analyses were conducted to address the presence of bias, the robustness of the observed overall summary effects, and how much of an impact the bias has on the estimated effects (Borenstein et al., 2009).

6.1 Reporting Bias Analyses

Undertaking a systematic review and meta-analysis evokes unique threats to internal validity of the overall study. Steps were taken to ensure that these threats were mitigated, or if they existed, assessing their impact on the results. There are many caveats to consider when interpreting the results of the meta-analyses. Such threats could expose themselves during the article retrieval and data extraction process. They may have included: article selection and extraction biases, and reporting biases. Steps were undertaken to minimize bias being introduced in the article selection and extraction processes by utilizing two independent reviewers and establishing a high-degree of inter-rater reliability between them.

In terms of reporting biases, there are a myriad of sources including: language bias (i.e. publication of research findings in a certain language), time lag bias (i.e. rapid or delayed publication of research findings), multiple publication bias (i.e. multiple or singular publication of research findings), location bias (i.e. journals with different levels of accessibility and indexing in databases), citation bias (i.e. citation or non-citation of research findings), and outcome reporting bias (i.e. selective reporting of some outcomes but not others) (Cochrane Handbook for Systematic Reviews, 2009). It was possible language reporting bias was introduced by not seeking or excluding studies that were not of English language. However, it was unlikely that the results produced were largely influenced by this source of bias as the majority of studies included were published in international journals where publication in the English language is common. The effects of time lag bias, multiple publication bias, location bias, and language bias were mitigated via utilizing a broad search strategy involving multiple electronic databases. Although grey literature was not sought out in this study, the effects of publication bias were not apparent, as the reporting bias analyses revealed that each of the experimental phases' funnel plots did not follow the publication bias model. The source of bias that was of concern was the outcome reporting bias. This source represents amount of studies that should have been included within the analysis but were not due to insufficient information.

Based on the results of Rosenthal's Fail- Safe *N*, it was reasonable to that the estimated effects (i.e. overall summary effects) for each of the experimental phase were not a product of bias. This is because each experimental phase yielded considerably large amounts of additional studies to 'nullify' their estimates. Thus, it was considered the estimated effects are robust against the reporting bias. There is evidence to suggest the presence of reporting bias in both the acquisition and transfer phases. Egger et al.'s Regression Intercept asymmetry found asymmetry within the acquisition phase funnel plot but not the transfer phase funnel plot (i.e. most likely due to small amount of studies). Duval and Tweedie's Trim & Fill method yielded higher estimates of the unbiased overall summary effects versus the observed estimates in the acquisition phases.

This finding does not fit with the model of publication bias (via Borenstein et al., 2009), as it was expected when observing a positive effect (i.e. direction of effect to the right), to have a gap on the left in the funnel plot where the smaller 'file drawer' studies would have resided if they were able to be located. Instead, another plausible source of funnel plot asymmetry could be from selective outcome reporting. Although this term classically suggests selective reporting due to the nature and direction of results (via Higgins & Green, Eds., 2009), the suggestion here is that since the analyses excluded a large number of studies (*n* = 46) that would have been included but lost due to lack of information/reporting, this may have led to missing studies who reported positive effects (i.e. <u>to the right</u> of the overall summary effect) and caused the observed overall summary effect to shift to the left. In addition, studies were excluded because their datasets violated the assumption of normality and homogeneity of variance (*n* = 17) may have had a similar impact. Taken collectively, these studies simply do not represent a random subset of all relevant studies; they are systematically different than the studies that are included in the analysis. The impact of these biases are said to be modest as there was no additional evidence to question the validity of the results of the syntheses. This was because the direction of the biases in both the acquisition and transfer are in the positive direction which suggests that the observed estimates are underestimated or conservative. <u>Thus, caution was warranted upon interpretation of the acquisition and transfer experimental phase results.</u>

6.2 Synthesis of Results

Before investigating the primary focus of the study, it was necessary to address the secondary purpose of the study first to ensure the viability of the primary focus of this study. Consistent with the general consensus of the literature (e.g. Wulf, 2013), the results of the syntheses failed to reject the hypothesis that the attentional focus effect would remain robust across the variety of studies with different tasks and across the learning, the retention of the learning, and the transfer of those tasks. A greater than zero overall summary effect in all three experimental phases confirm that adopting an external focus versus an internal focus is beneficial towards the immediate performance, learning, and transfer of motor skill. These results offer further solidification of the attentional focus effect within the motor control literature by broadening the supporting evidence base. More importantly, these results provide strong evidence against the studies that report null results. Since the articles that were included in the analyses were sought in a systematic method (i.e. studies that include explicit external [effects of the movement] and internal [body movements] focus groups/conditions), it was reasonable to attribute the findings of studies with null results solely to artifacts of methodological inconsistencies. These included the amount of information residing within an instructional/feedback cue (e.g. Poolton, Maxwell, Masters, & Raab, 2006b; Emanuel, Jarus, & Bart, 2008); the use of visual feedback confounding the attention focus effect (e.g. de Bruin et al., 2009); the design of the experiment ‘cancelling’ of the attentional focus effect (e.g. Castaneda & Gray, 2007); and the use of an inappropriate outcome measure to measure performance of a task (e.g. Lawrence, Gottwald, Hardy, & Khan, 2011; Schorer, Jaitner, Wollny, Fath, & Baker, 2012).

6.3 Subgroup Analyses

It was hypothesized that this external focus advantage would vary across studies with these different characteristics, such that task group membership of either discrete or continuous and open or closed tasks could explain for the proportion of the dispersion. For the acquisition phase, heterogeneity was found within the discrete subgroup but not the continuous subgroup. This dispersion within the discrete subgroup suggested that the tasks identified as discrete varied on a continuum of ‘discreteness’. According to Schmidt and Lee (2005), this continuum is temporal as some discrete tasks can take a very small period of time to complete (e.g. dart throwing) while some take a considerable period of time to complete (e.g. pressing a sequence of keys). There were a variety of tasks within this subgroup that could have explained for this dispersion (e.g. golf shots, dart throws, basketball shots etc.). For continuous subgroup, tasks remained homogeneous as the majority of tasks within this subgroup involved balancing. Differences emerged between discrete and continuous task subgroups as a subsequent test to address the proportion of overall true dispersion explained by this subgroup difference revealed an R^2 index less than 0.0. Borenstein et al. (2009) suggested that although the R^2 index spans a range between 0.0 and 1.0, it is possible for this value to fall outside this range because of within-study error, or sampling error. Without this critical piece of information, the relationship between the discrete/continuous task dimensions and the attentional focus effect could not be established within the contexts of the proposed constraints-led framework. Imprecise estimates of individual studies may have subsequently resulted in imprecise overall summary effect estimates. The source of dispersion within a subgroup may have also contributed to the inability to obtain an R^2 index because it was identified as ‘within-studies error’. That is, the source of error within subgroups may have hindered the ability of finding true differences between subgroups. Methods of improving this estimate (i.e. taking into account the sources of sampling error) are discussed in detail in the limitation section.

Overall, the results of this subgroup analysis reflect previous literature in terms of differential immediate performance effects between discrete and continuous tasks. That is, tasks with greater task difficulty hold a greater magnitude of attentional focus effect (Wulf et al., 2007). The studies that were conducted with discrete tasks yielded a higher overall summary effect versus the studies that were conducted with continuous tasks. Based on Guadagnoli & Lee’s (2004) definition of nominal task difficulty, discrete tasks hold a higher degree of nominal task difficulty relative to continuous tasks since they have greater perceptual-motor requirements. The former statement is substantiated by Spencer et al.’s (2007) study who found greater cerebellar activity (i.e. greater informational processing) during discrete movements versus continuous movements.

For the retention phase, no heterogeneity was found within the discrete and continuous task subgroups. This suggested that the tasks within discrete and continuous subgroups were homogeneous (i.e. they did not vary significantly on the continuum of discrete and continuous tasks, respectively). Heterogeneity was not found between discrete and continuous subgroups. Thus, the subsequent test to estimate the proportion of overall true dispersion explained by subgroup membership was not qualified. Again, without this critical piece of information the relationship between the discrete/continuous task dimensions on the attentional could not be established within the contexts of the proposed constraints-led framework.

Overall, the results of this subgroup analysis contradict previous literature in terms of the differential retention of learning effects between discrete and continuous tasks. The difference between discrete and continuous tasks in retention tests has been well documented motor learning literature such that, the results consistently disclose that continuous tasks hold a very high degree of retention while discrete tasks fare poorly in these tests. Although the mechanisms for this difference are not fully understood, they do provide insight towards the explanation of the findings in the retention and transfer phases. One plausible mechanism outlined by Schmidt and Lee (2005) is the amount of original learning. It is known that there is a positive relationship between retention and the amount of original (i.e. retention increases as the amount of original learning increases). This is substantiated once the subtle, yet apparent differences emerge between discrete and continuous task in the context of the original learning phase (i.e. acquisition) and trials during the retention test. With the number of trials held constant, continuous tasks tend to be more ‘practiced’ versus discrete tasks as the absolute duration of performing continuous tasks in experiments is generally longer than performing discrete tasks. For instance, if a trial is 60 seconds for a continuous task, considerably more learning can occur versus a discrete task, whose trial can occur rapidly. Another mechanism of this difference is how discrete and continuous task were assessed. The concern here was that the retention of learning is measured in terms of absolute learning, which is the assessment of performance on the initial trials of the retention tests. This distinction makes the retention test systematically different between continuous and discrete tasks because the performance of a continuous task trial is essentially averaged across its duration. Thus, the first initial moment of a continuous trial could potentially show retention loss, but it would fail to be identified (Schmidt and Lee, 2005). The implications of this speculation could mean that the retention results in continuous tests are potentially overestimated; meaning that the difference between discrete task retention test performance may seem to be, but in reality may not exist at all. Based on these mechanisms, it would have been expected that the continuous subgroup hold a greater overall summary effect estimate versus the discrete subgroup. However, the results indicated a higher overall summary effect for the discrete subgroup. It may be possible that the overall summary effect estimates were artifacts of imprecision of individual study estimates as wide confidence intervals appeared in both estimates of the overall summary effect for discrete and continuous task subgroups. More importantly, it could be possible that the amount of absolute learning that occurred in the acquisition phase in the presence of attentional focus and the assessment duration of the retention phase played a factor in the results by contributing to 'within-study error'. These apparent sources of imprecision of estimates are discussed in the following section.

For the transfer phase, heterogeneity was found within the continuous task subgroup but not within the discrete task subgroup. This dispersion within the continuous group subgroup suggested that the tasks identified as continuous varied on a continuum of 'continuous-ness'. Since continuous tasks are defined by an arbitrary point in time, there were tasks with varying time lengths that were implemented. For instance, Jackson & Holmes (2011) used 90 second trials for their stabilometer task and Jarus et al. (2015) used 30 second trials for their manual tracking task. The concern here was that because the tasks varied in terms of the degree of continuality (i.e. duration of task performed), this may have attributed to 'within-studies error'. The significance of this is discussed in the following section. More importantly, heterogeneity was not found between discrete and continuous subgroups. Thus, the subsequent test to estimate the proportion of overall true dispersion explained by subgroup membership was not qualified. Again, without this critical piece of information the relationship between the discrete/continuous task dimensions on the attentional could not be established within the contexts of the proposed constraints-led framework.

Overall, the results of this subgroup analysis contradict previous literature in terms of the differential transfer of learning effects between discrete and continuous tasks. The difference in overall summary effect between discrete and continuous task subgroups in the transfer phase was inferred from the amount of original learning that occurred in the acquisition phase. According to Schmidt and Lee (2005), there are two principles derived from the consensus literature that the transfer of learning adheres to. These include: the similarity of tasks and that the transfer of learning is small, yet positive. Schmidt and Lee (2005) suggested that the process of transfer is a highly specific and selective process, such that there needs to be a high degree of task similarly. Thus, based on the differences from the acquisition phase, it was expected that the discrete tasks would hold a greater amount of transfer of skill versus continuous task when there is a high degree of similarity between original and transfer tasks. However, the results indicated a higher overall summary effect for discrete subgroup versus continuous subgroup. Likewise with the retention phase, the observed estimates could be an artifact of the imprecision associated individual study estimates, which translated into wide confidence intervals of each subgroup. It can also be attributed to a low amount of power as there were a small amount of studies in each subgroup (eight and seven studies in the discrete and continuous tasks, respectively). Lastly, it was unclear whether the observed overall summary effect estimates (i.e. within-study error) reflected the degree of similarity between practiced and transferred skills in individual as this standpoint was not formally tested.

In summary, the syntheses of results for each of experimental phase yielded interesting results. First, interpretation of the acquisition and transfer syntheses results needed to be interpreted with caution as reporting bias analyses revealed the observed estimate of the overall summary effects to be underestimated. Additional pieces of evidence supporting the external focus advantage were provided as the overall summary effect (i.e. representative of the standardized mean difference between external and internal focus groups/conditions) in each experimental phase were greater than zero. A closer examination of the dispersion of individual study effects from the overall summary effect revealed heterogeneity in the acquisition phase such that, the overall summary effect in the discrete task subgroup was greater than versus the continuous task subgroup. An attempt to address proportion of variance explained by these subgroups failed to establish a relationship between task constraint and the attentional focus effect. No heterogeneity was found between subgroups in the retention and transfer phases, thus failing to establish this relationship as well. Failure to establish the relationship between task constraint and the attentional focus effect was attributed to the differential effects of retention of learning on discrete and continuous and also a lack of power for the transfer of learning. Another possibility that transcends all three experimental phases was the imprecision of estimates for individual studies as for the overall summary effects. A detailed explanation of addressing sources of imprecision is brought forth in the following section.

6.4 Limitations

Amendments to this current study mainly revolve around mitigating the biases introduced in the analyses as well as improving the precision of the estimates of the individual studies. Applying a grey literature would help reduce publication bias (i.e. even further if the studies with insufficient data were included). In addition, re-contacting authors to obtain sufficient data of the articles that were excluded. These methods can serve the dual purposes of reducing the outcome reporting bias and improving the precision of the overall summary estimates and variance. Perhaps the single most effective method to improve precision of the estimates is to utilize sensitivity analyses. Sensitivity analyses function to address the robustness of the overall summary effect and its variance in terms of the assumptions and decisions that are determined a priori (Borenstein et al., 2009). They ask questions such as: what is the impact of the statistical methods that were used on the conclusions drawn from the analysis; and how much might the results change if different a different decision model had been utilized?

The first question resonates with the decision to collapse across all comparison groups and multiple outcomes within each applicable study to obtain an effect size and variance estimate. This was necessary in order to prevent an erroneous computation of the overall summary effect's variance (i.e. which would have ultimately led to an inflated Q-test based on ANOVA, thus heterogeneity results); however, it led to an underestimate of the amount of unique information (i.e. study weight) each study with multiple comparisons/outcomes provided to the analysis. This ultimately led to a conservative estimate of the overall summary variance (and to some degree, the overall summary effect). In this particular situation, because the correlation values between multiple comparisons outcomes within these applicable studies were not reported, collapsing across these groups means assigning an R-value of 1.00 (i.e. assuming full dependency of each other). To estimate the amount of unique information contributed by dependent comparisons and/or multiple outcomes, Borenstein et al. (2009) suggested using correlation estimates of the comparisons and/or multiple outcomes and incorporating these into the formulas that estimate variance of the individual studies. These composite scores can then be subjected to multiple meta-analyses to establish an estimate of the overall summary effect over a range of correlations. These scores can then be subjected to sensitivity analyses to determine which correlational value is most suitable to use that allows for attribution of unique information from those multiple comparisons/outcome without leading to incorrect estimates of the overall summary variance (and potential overall summary effect).

The use of sensitivity analysis could also be used to disclose more specific nuances that have been anecdotally identified in this study as well as within the literature, but were associated as the ‘within-studies error’. It can be applied to examine the interaction of the ‘absolute learning period’ of discrete and continuous tasks with the attentional focus effect. That is, it could address the potentiality (or lack thereof) of the attentional focus effect differing in studies that utilize discrete or continuous task whose trial durations and trial amounts different while acquiring the skill and also during retention and transfer test. It can also be applied to address the heterogeneity of the discrete and continuous task subgroups. That is, is the effect robust enough against heterogeneity discrete and continuous subgroups, whose tasks vary in the amount of time needed to execute the task (i.e. dictated by the task or by an arbitrary point in time)? Sensitivity analyses could also be explored to investigate and verify established assumptions within the attentional focus literature. For instance, Wulf et al. (1998) suggested that the instructional cues of an internal and external focus remain as closely similar as possible, only to differ in terms of referring to body movements and the effects of the movements, respectively. Could the amount of information imposed within an instructional cue produce an artifact of influence on the magnitude of the attentional focus effect? Sensitivity analyses could also be explored to investigate possible dispersion of effect due to the type of outcome measure used. This can be conducted using a subgroup analysis with different studies and having the differential outcome measures (i.e. spatial and temporal), but it warrants sensitivity analyses because the majority of studies report multiple outcomes either the spatial or temporal dimension.

6.5 Practical Implications and Future Directions

This study is particularly important for the advancement of the attentional focus research field. Currently, a gap exists between what is known and what is applied outside a laboratory setting. For instance, Durham, van Vliet, and Badger (2009) found that video recorded interactions of eight physiotherapists and eight stroke patients revealed the majority of feedback statements (236 of 247) were identified as an internal attentional focus type. Moreover, it has been identified by Porter, Wu, and Partridge (2010) that 84.6% of athletes who competed at United States track and field national championships had coaches administering instructions relating to their bodies. A large majority of these athletes (69.2%) also reported that they used internal focus while competing. This inherent gap between knowledge and practice is one that hinders the widespread use of this known advantage (i.e. towards the acquisition, retention, and transfer of motor skills) for coaching and rehabilitation practitioners giving instructional cues and/or feedback cues to their respective players and patients. It is hoped that once the framework is established, it could be utilized to address specific settings where the external focus advantage lends its greatest influence. By using the framework (Figure 11) as a guide, coaches and practitioners can determine (based on their given circumstances) which combinations of individual, task, and environmental constraint would yield the greatest influence on the external focus advantage on their players and patients. They would also be able to apply the framework as a predictive tool to attain the greatest attentional focus benefit based on any given situation (i.e. combination of constraints). This has a profound importance to any stakeholders involved in the process of acquisition, retention, and transfer of motor skills as it would potentially aid in facilitating efficiency and proficiency of these processes.

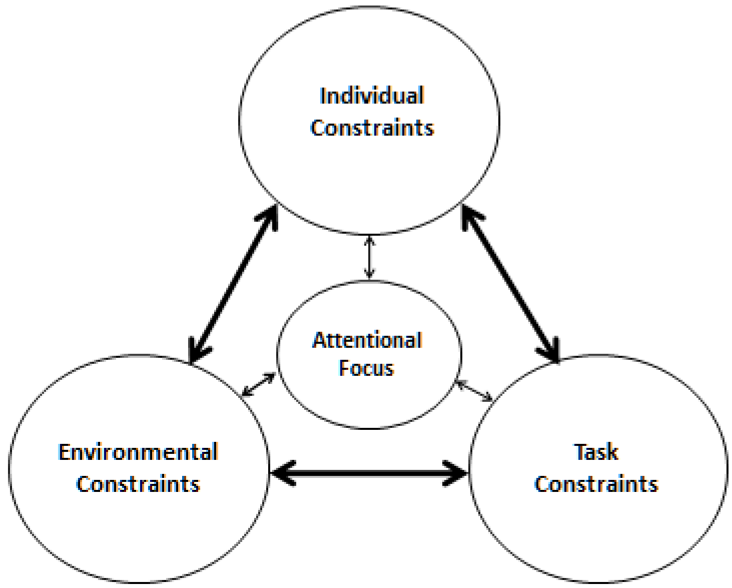

Figure 11. **The proposed constraints-led model for the attentional focus effect in sensorimotor task performance and learning.**

The bidirectional arrows between attentional focus and the constraints and between the constraints illustrate the potential for different interactions over time.

6.6 Moving Towards an Established Framework

On a grander scale of this study, the methods set forward can be replicated to investigate the other study-level characteristics ascribed earlier to further establish validate the proposed framework (e.g. Figure 12). Additional meta-analytical techniques such as meta-regression could be used to address the potentiality of either three constraints interacting with each other and to the overall summary effect. The subgroups that yield statistical significance could function as the covariates in the analysis with the subgroups that fall under the same categorical constraint (i.e. intrinsic, environment, and task) being clustered together. For instance, if the 'age' and 'level of expertise' were identified from the subgroup analyses as being related to the overall summary effect (i.e. yielding a statistical significance), they could be entered into the same meta-regression analysis. In order to differentiate between the constraints, three separate enter-method meta-regression analyses will be performed to ultimately determine possible predictiveness of constraint on the overall summary effect. Coefficients for the covariate(s) can be obtained and subjected to the Q-test based analysis of variance (i.e. test of significance of the slope). Moreover, the goodness of fit test could be utilized to assess whether the unexplained variance is zero. The magnitude of the relationship can then be reported via the regression equation with its respective covariate along with an x-y plot to address the slope of the regression line and each study and its relative weight. Calculations of the lower and upper confidence intervals marked at the 5th and 95th percentiles, respectively for each co-variate. Calculations for the proportion of variance explained by each of the covariates will then follow (Eq. 23). This procedure could be repeated for the other constraints.

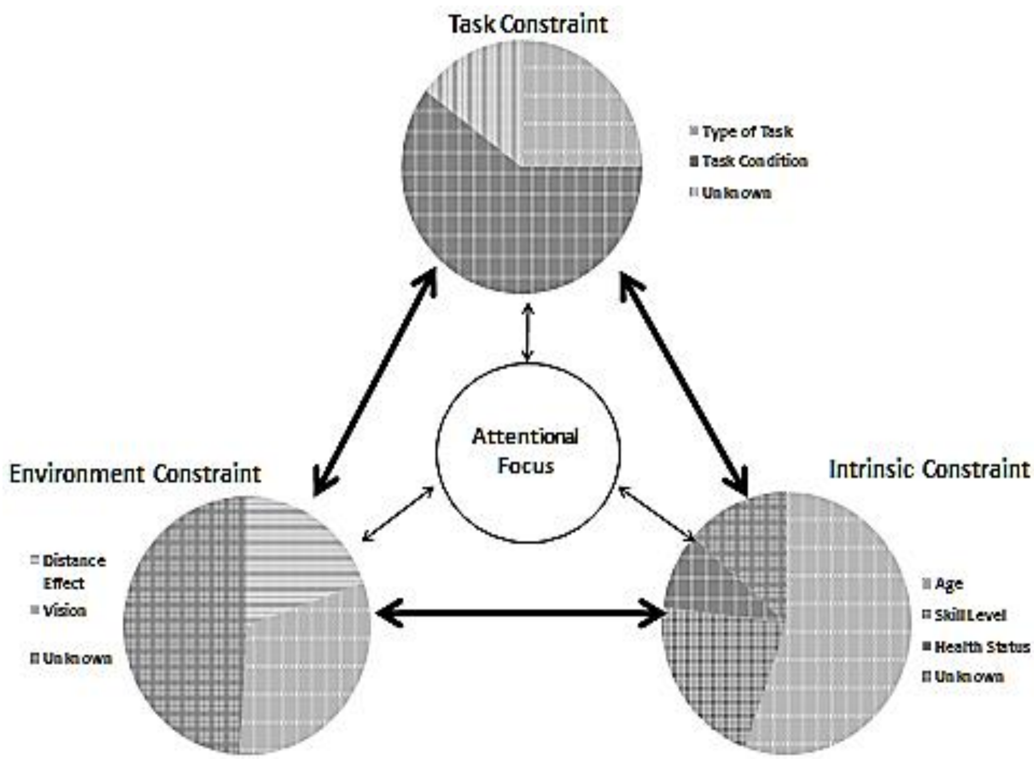

Figure 12. **<u>The proposed developmental systems approach to attentional focus in sensorimotor task performance and learning.</u>**

It features hypothetical causal components in each constraint to depict how much of a specific characteristic (that is seen across the studies) can attribute and/or interact with the observed effect.

6.7 Summary

This study was the first study in the area of attentional focus literature to collectively investigate all pertinent studies over the past 15 plus years via utilizing a systematic review and meta-analyses. As Crick and Koch (2003) describes, a framework is intended to approach scientific issues in a newfound perspective often in the process of suggesting testable hypotheses. Although this study did not establish a portion of the theoretical framework pertaining to the task constraint primarily due to imprecision from individual study effect estimates, theoretical methods were ultimately applied with recommendations made to improve these methods in future studies. This study will lead the way for future studies that build on this theoretical framework with a tested and tried approach towards uncovering other study-level characteristic present across the literature and its effect on the attentional focus effect. Lastly, this study has additional offerings/functions; such that, it has inevitably established a paradigm for future studies investigating the attentional focus effect with different tasks, in different settings, and with different individuals to follow.

REFERENCES

Abernethy, B. (1988). Dual task methodology and motor skills research: Some applications and methodological constraints. *Journal of Human Movement Studies*, 14, 101 - 132.

An, J., Wulf, G., & Kim, S. (2013). Increased carry distance and X-factor stretch in golf through an external focus of attention. *Journal of Motor Learning and Development*, 2–11.

Bell, J. J., & Hardy, J. (2009). Effects of Attentional Focus on Skilled Performance in Golf. *Journal of Applied Sport Psychology*, *21*(2), 163–177.

Bootsma, R., & Wieringen, P. Van. (1990). Timing an attacking forehand drive in table tennis. *Journal of Experimental Psychology*, *16*(l), 21–29.

Borenstein, M., Hedges, L., Higgins, J., & Rothstein, H. (2009). *Introduction to meta-analysis*. Chichester, UK: John Wiley & Sons, Ltd.

Castaneda, B., & Gray, R. (2007). Effects of focus of attention on baseball batting performance in players of differing skill levels. *Journal of Sport & Exercise Psychology*, *29*(1), 60–77.

Chamboron, S., Berberian, B., Delbecque, L., Ginhac, D., & Cleeremans, A. (2009). Implicit motor learning in discrete and continuous tasks: Toward a possible explanation of discrepant results. *Handbook of Motor Skills: Development, Impairment, and Therapy*, 139-155.

Chiviacowsky, S., Wulf, G., & Avila, L. T. G. (2013). An external focus of attention enhances motor learning in children with intellectual disabilities. *Journal of Intellectual Disability Research, 57*(7), 627-634.

Chiviacowsky, S., Wulf, G., Wally, R. (2010). An external focus of attention enhances balance learning in older adults. *Gait & Posture, 32,* 572-575.

Chow, J. Y., Woo, M. T., & Koh, M. (2014). Effects of external and internal attention focus training on foot-strike patterns in running. *International Journal of Sports Science & Coaching, 9*(2), 307-320.

Christina, B., & Alpenfels, E. (2014). Influence of attentional focus on learning a swing path change. *International Journal of Golf Science, 3,* 35-49.

Cohen, J. (1988). *Statistical power analysis for the behavioral sciences* (2nd ed.). Hillsdale, NJ: Erlbaum.

Crick, F., & Koch, C. (2003). A framework for consciousness. *Nature Neuroscience, 6,* 119-126.

Davids, K.W., Button, C., & Bennett, S.J. (2008) *Dynamics of skill acquisition : a constraints-led approach.* Champaign, IL: Human Kinetics.

De Bruin, E. D., Swanenburg, J., Betschon, E., & Murer, K. (2009). A randomised controlled trial investigating motor skill training as a function of attentional focus in old age. *BMC Geriatrics, 9,* 15.

Durham, K., van Vliet, P. M., Badger, F., & Sackley, C. (2009). Use of information feedback and attentional focus of feedback in treating the person with a hemiplegic arm. *Physiotherapy Research International, 14*(2), 77-90.

Duval, S., & Tweedie, R. (2000a). A nonparametric ‘trim and fill’ method of accounting for publication bias in meta-analysis. *Journal of the American Statistical Association*, *95*, 89–98.

Duval, S., & Tweedie, R. (2000b). Trim and fill: A simple funnel-plot-based method of testing and adjusting for publication bias in meta-analysis. *Biometrics, 56,* 455–463.

Egger, M., Davey Smith, G., Schneider, M., & Minder, C. (1997). Bias in meta-analysis detected by a simple, graphical test. *British Medical Journal, 315*, 629–634.

Emanuel, M., Jarus, T., & Bart, O. (2008). Effect of focus of attention and age on motor acquisition, retention, and transfer: a randomized trial. *Physical Therapy, 88*(2).

Fitts, P. M. (1954). The information capacity of the human motor system in controlling the amplitude of movement. *Journal of Experimental Psychology*, *47*, 381-391.

Gesell, A. (1928). Infancy and human growth. New York: Macmillan.

Glass, G.V., McGaw, B., & Smith, M. (1981). *Meta-analysis in social research*. Beverly Hills, CA: Sage.

Gokeler, A., Benjaminse, A., Welling, W., Alferink, M., Eppinga, P., & Otten, B. (2014). The effects of attentional focus on jump performance and knee joint kinematics in patients after ACL reconstruction. Physical Therapy in Sport, 1-7.

Guadagnoli, M. A., & Lee, T. D. Challenge Point: A framework for conceptualizing the effects of various practice conditions in motor learning. *Journal of Motor Behavior, 36*(2), 212-224.

Hedges, L.V. (1981). Distribution theory for Glass's estimator of effect size and related estimators. *Journal of Educational Statistics*, *6*, 107-128.

Hedges, L.V. & Olkin, I. (1985). *Statistical methods for meta-analysis*. New York: Academic Press.

Higgins, J. P., & Green, S. (Eds) (2008). Front matter, in Cochrane Handbook for Systematic Reviews of Interventions: Cochrane Book Series. Chichester, UK: John Wiley & Sons.

Higgins, J. P., Thompson, S. G., & Spiegelhalter, D. J. (2009). A re-evaluation of random-effects meta-analysis. Journal of the Royal Statistics Society, 172(1), 137-159.

Hossener, E.-J., & Wenderoth, N. (2007). Gabriele Wulf: On a attention focus and motor learning. *E-Journal Bewegung Und Training*, *1*, 1–64.

Hreljac, A. (2000). Stride smoothness evaluation of runners and older athletes. *Gait & Posture*, 11, 199 - 206.

Jackson, B. H., & Holmes, A. M. (2011). The Effects of Focus of Attention and Task Objective Consistency on Learning a Balancing Task. *Research Quarterly for Exercise and Sport*, *82*(3), 574–579.

Jarus, T., Ghanouni, P., Abel, R. L., Fomenoff, S. L., Lundberg, J., Davidson, S., Caswell, S., Bickerton, L., & Zwicker, J. G. (2015). *Research in Developmental Disabilities, 37*, 119-126.

Julesz, B., & Bergen, J. (1983). Human factors and behavioral science: Textons, the fundamental elements in preattentive vision and perception of textures. *Bell System Technical Journal, The*.

Kal, E. C., van der Kamp, J., & Houdijk, H. (2013). External attentional focus enhances movement automatization: a comprehensive test of the constrained action hypothesis. *Human Movement Science, 32*(4), 527–39.

Kalkhoran, J. F. & Shariati, A. (2014). The effect of attentional-focus instruction on peripheral transfer from dominant hand to non-dominant hand and vice versa in basketball dribbling. *Pamukkale Journal of Sport Sciences, 5*(2), 75-84.

Kasper, R. W., Elliott, J. C., & Giesbrecht, B. (2012). Multiple measures of visual attention predict novice motor skill performance when attention is focused externally. *Human Movement Science*, *31*(5), 1161–1174.

Keele, S.W. (1968). Movement control in skilled motor performance. *Psychological Bulletin*, 70, 387-403.

Keller, M., Lauber, B., Gottschalk, M., & Taube, W. (2014). Enhanced jump performance when providing augmented feedback compared to an external or internal focus of attention. *Journal of Sports Sciences*, 1-9. DOI:10.1080/02640414 .2014.984241.

Klostermann, A., Kredel, R., Hossner, E. J. (2014). On the interaction of attentional focus and gaze: The quiet eye inhibits focus-related performance decrements. *Journal of Sport & Exercise Psychology*, *36*, 392-400.

Kukar, C., Zia, N., Sehgal, S., & Khushwaha, S. (2013). Effect of external and internal focus of attention on acquisition, retention, and transfer phase of motor learning in Parkinson's disease. *Hong Kong Physiotherapy Journal*, 31, 88-94.

Land, W. M., Frank, C., & Schack, T. (2014). The influence of attentional focus on the development of skill representation in a complex action. *Psychology of Sport and Exercise*, *15,* 30-38.

Land, W. M., Tenenbaum, G., Ward, P., & Marquardt, C. (2013). Examination of visual information as a mediator of external focus benefits. *Journal of Sport & Exercise Psychology*, *35*(3), 250–9.

Landers, M., Wulf, G., Wallmann, H., & Guadagnoli, M. (2005). An external focus of attention attenuates balance impairment in patients with Parkinson's disease who have a fall history. *Physiotherapy*, *91*(3), 152–158.

Laufer, Y., Rotem-Lehrer, N., Ronen, Z., Khayutin, G., & Rozenberg, I. (2007). Effect of Attention Focus on Acquisition and Retention of Postural Control Following Ankle Sprain. *Archives of Physical Medicine and Rehabilitation*, *88*(1), 105–108.

Lawrence, G. R., Gottwald, V. M., Hardy, J., & Khan, M. a. (2011). Internal and external focus of attention in a novice form sport. *Research Quarterly for Exercise and Sport*, *82*(3), 431–41.

Leibovich, T. & Henik, A. (2014). Comparing performance in discrete and continuous comparison tasks. *The Quarterly Journal of Experimental Psychology, 67*(5), 899-917.

Liberati, A., Altman, D. G., Tetzlaff, J., Mulrow, C., Gøtzsche, P. C., Ioannidis, J. P. A, Clarke, M., Devereaux, P. J., Kleijnen, J., & Moher, D. (2009). The PRISMA statement for reporting systematic reviews and meta-analyses of studies that evaluate health care interventions: explanation and elaboration. *PLoS Medicine*, *6*(7), e1000100.

Lidor, R. & Ziv, G. (2013). The effect of attention allocation instructions on self-paced task performance under quiet and distracted conditions. *Journal of Applied Sport Psychology, 25*, 478-492.

Light, R.J., & Pillemer, D.B. (1984). *Summing up: The Science of Reviewing Research*. Cambridge, MA: Harvard University Press.

Lohse, K. R. (2012). The influence of attention on learning and performance: Pre-movement time and accuracy in an isometric force production task. *Human Movement Science, 31*(1), 12–25.

Lohse, K. R., & Sherwood, D. E. (2011). Defining the focus of attention: effects of attention on perceived exertion and fatigue. *Frontiers in Psychology, 2*(November), 332.

Lohse, K. R., Sherwood, D. E., & Healy, A. F. (2010). How changing the focus of attention affects performance, kinematics, and electromyography in dart throwing. *Human Movement Science*, *29*(4), 542–555.

Lohse, K. R., Sherwood, D. E., & Healy, A. F. (2011). Neuromuscular effects of shifting the focus of attention in a simple force production task. *Journal of Motor Behavior, 43*(2), 173-184.

Lohse, K. R., Sherwood, D. E., & Healy, A. F. (2014). On the advantage of an external focus of attention: A benefit to learning or performance? *Human Movement Science*, 33, 120-134.

Makaruk, H., Porter, J. M., Czaplicki, A., Sadowski, U., & Sacewicz, T. (2015). The role of attentional focus in plyometric training. The *Journal of Sports Medicine and Physical Fitness*, *52*, 319-327.

Makaruk, H., Porter, J. M., & Makaruk, B. (2013). Acute effects of attentional focus on shot put performance in elite athletes. *Kinesiology, 45*(1), 55-62.

Marchant, D. C., Clough, P. J., & Crawshaw, M. (2007). The effects of attentional focusing strategies on novice dart throwing performance and Their task experiences. *International Journal of Sport and Exercise Psychology*, *5*(3), 291–303.

Marchant, D. C., Clough, P. J., Crawshaw, M., & Levy, A. (2009). Novice motor skill performance and task experience is influenced by attentional focusing instructions and instruction preferences. *International Journal of Sport and Exercise Psychology*, 7, 488-502.

Marchant, D. C., Greig, M., Bullough, J., & Hitchen, D. (2011). Instructions to adopt an external focus enhance muscular endurance. *Research Quarterly for Exercise and Sport*, *82*(3), 466–73.

Marchant, D., Greig, M., & Scott, C. (2009). Attentional focusing instructions influence force production and muscular activity during isokinetic elbow flexions. *The Journal of Strength & Conditioning Research, (20)*, 2358–2366.

Maurer, H., & Munzert, J. (2013). Influence of attentional focus on skilled motor performance: Performance decrement under unfamiliar focus conditions. *Human Movement Science, 32*, 730-740.

McGraw, M.B. (1943). The neuromuscular maturation of the human infant. New York: Columbia University Press (Reprinted by Hafner, 1963).

McNevin, N. H., Shea, C. H., & Wulf, G. (2003). Increasing the distance of an external focus of attention enhances learning. *Psychological Research*, *67*(1), 22–9.

McNevin, N. H., & Wulf, G. (2002). Attentional focus on supra-postural tasks affects postural control. *Human Movement Science*, *21*(2), 187–202.

McNevin, N., Weir, P., & Quinn, T. (2013). Effects of Attentional Focus and Age on Suprapostural Task Performance and Postural Control. *Research Quarterly for Exercise and Sport*, *84*(1), 96–103.

Morris, S. B. (2008). Estimating effect sizes from pretest-posttest-control group designs. *Organizational Research Methods*, *11*(2), 364-386.

Mullen, R., Faull, A., Jones, E. S., & Kingston, K. (2012). Attentional focus and performance anxiety: effects on simulated race-driving performance and heart rate variability. *Frontiers in Psychology, 3*, 1-10.

Müller, H., & Loosch, E. (1999). Functional variability and an equifinal path of movement during targeted throwing. *Journal 01 Human Movement Studies*, 103–126.

Neumann, D. L., & Brown, J. (2013). The Effect of Attentional Focus Strategy on Physiological and Motor Performance During a Sit-Up Exercise. *Journal of Psychophysiology*, *27*(1), 7–15.

Newell, K.M. (1984). In J. Thomas (Ed.), *Motor development during childhood and adolescence*, pp. 106-120. Minneapolis, MN: Burgess.

Newell, K.M. (1985). Coordination, control and skill. In D. Goodman, R.B. Wilburg, & I.M. Franks (Eds.), *Differing perspectives in motor learning, memory, and control*, pp. 295-317. Amsterdam: Elsevier Science.

Newell, K.M. (1986). Constraints on the development of coordination. In M.G. Wade & H.T.A Whiting (Eds.), *Motor development in children: Aspects of coordination and control*, pp. 341-361. Amsterdam: Martinus Nijhoff Publishers.

Ong, N. T., Bowcock, A., & Hodges, N. J. (2010). Manipulations to the timing and type of instructions to examine motor skill performance under pressure. *Frontiers in Psychology*, *1*, 196.

Orwin, R. G. (1994). Evaluating coding decisions. In: Cooper H., Hedges L. V. (Eds.). *The Handbook of Research Synthesis*. New York, NY: Russell Sage Foundation.

Polskaia, N., Richer, N., Dionne, E., & Lajoie, Y. (2015). Continuous cognitive task promotes greater postural stability than an internal or external focus of attention. *Gait & Posture, 41*, 454-458.

Parr, R., & Button, C. (2009). End-point focus of attention: Learning the "Catch" in Rowing. *International Journal of Sport Psychology*, *40*(4), 616–635.

Patterson, T. (2001). Constraints: An integrated viewpoint. *Illuminare, 7 (1)*, *7*(1), 30–38.

Phillips, E., Davids, K., Renshaw, I., & Portus, M. (2010). Expert performance in sport and the dynamics of talent development. *Sports Medicine (Auckland, N.Z.)*, *40*(4), 271–83.

Poolton, J. M., Maxwell, J. P., Masters, R. S. W., & Raab, M. (2006a). Benefits of an external focus of attention: common coding or conscious processing? *Journal of Sports Sciences*, *24*(1), 89–99.

Poolton, J. M., Maxwell, J. P., Masters, R. S. W., & Raab, M. (2006b). Benefits of an external focus of attention: common coding or conscious processing? *Journal of Sports Sciences*, *24*(1), 89–99.

Porter, J., Anton, P., & Wu, W. (2012). Increasing the distance of an external focus of attention enhances standing long jump performance. *The Journal of Strength & …*, *26*(9), 2389–2393.

Porter, J. M., Nolan, R. P., Ostrowski, E. J., & Wulf, G. (2010). Directing attention externally enhances agility performance: a qualitative and quantitative analysis of the efficacy of using verbal instructions to focus attention. *Frontiers in Psychology*, *1*(November), 216.

Porter, J. M., Ostrowski, E. J., Nolan, R. P., & Wu, W. F. W. (2010). Standing long-jump performance is enhanced when using an external focus of attention. *Journal of Strength and Conditioning Research / National Strength & Conditioning Association*, *24*(7), 1746–1750.

Porter, J.M., Wu, W.F.W., & Partridge, J.A. (2010). Focus of attention and verbal instructions: Strategies of elite track and field coaches and athletes. *Sport Science Review*, *19*, 199_211.

Prinz, W. (1984). Modes of linkage between perception and action. In W. Prinz AF Sanders (Eds.), Cognition and Motor Processes, pp. 185–194. Berlin, DE, Heidelberg, DE, New York, NY: Springer.

Prinz, W. (1990).A common coding approach to perception and action. In O. Neumann &W. Prinz (Eds.), *Relationships between Perception and Action*, pp. 167-201. Berlin, DE: Springer-Verlag.

Prinz, W. (1997). Perception and action planning. *European Journal of Cognitive Psychology*, *9*, 129-154.

Renshaw, I., Davids, K., Phillips, E., et al. (2012). Developing talent in athletes as complex neurobiological systems. In J. Baker, S. Cobley, & J. Schorer (Eds.), *Talent Identification and Development in Sport: International Perspectives*, pp. 64-80. London, UK: Routledge.

Richman, J.S., & Moorman, J.R. (2000). Physiological time-series analysis using approximate entropy and sample entropy. *American Journal of Physiology Heart and Circulatory Physiology*, 278, H2039-H2049.

Rosenthal, R. (1979). The ‘File drawer problem’ and tolerance for null results. *Psychological Bulletin, 86*, 638–641.

Rotem-Lehrer, N., & Laufer, Y. (2007). *Effect of focus of attention on transfer of a postural control task following an ankle sprain. The Journal of orthopaedic and sports physical therapy* (Vol. 37, pp. 564–569).

Rothman, K.J. (1976). Causes. *American Journal of Epidemiology, 104*(5), 87–92.

Saemi, E., Porter, J. M., Ghotbi-Varzaneh, A., Zarghami, M., & Maleki, F. (2012). Knowledge of results after relatively good trials enhances self-efficacy and motor learning. *Psychology of Sport and Exercise*, *13*(4), 378–382.

Schmidt, R.A. (1975). A schema theory of discrete motor skill learning. *Psychological Review*, 82, 225-260.

Schmidt, R. A., & Lee, T. D. (2005). *Motor control and learning: A behavioral emphasis*, 3rd Ed., pp. 455. Champaign, IL: Human Kinetics.

Schorer, J., Jaitner, T., Wollny, R., Fath, F., & Baker, J. (2012). Influence of varying focus of attention conditions on dart throwing performance in experts and novices. *Experimental Brain Research*, *217*(2), 287–97.

Schücker, L., Hagemann, N., Strauss, B., & Völker, K. (2009). The effect of attentional focus on running economy. *Journal of Sports Sciences*, *27*(12), 1241–8.

Shafizadeh, M., Platt, G. K., & Bahram, A. (2013). Effects of focus of attention and type of practice on learning and self-efficacy in dart throwing. *Perceptual & Motor Skills: Motor Skills & Ergonomics*, 117(1), 182-192.

Shea, C., & Wulf, G. (1999). Enhancing motor learning through external-focus instructions and feedback. *Human Movement Science*, *18*, 553–571.

Shemmell, J., Tresilian, J. R., Riek, S., Barry, B. K., & Carson, R.G. (2005). Neuromuscular adaptation during skill acquisition on a two degree-of-freedom target acquisition task: Dynamic movement. *Journal of Neurophysiology*, 94, 3058-3068.

Spencer, R. M. C., Verstynen, T., Brett, M., & Ivry, R. (2007). Cerebellar activation during discrete and not continuous timed movements: A fMRI study. *Neuroimage, 36*(2), 378-387.

Sulewski, A. L., Tripp, B. L., & Wikstrom, E. A. (2012). Acquisition and transfer of postural control among individuals with chronic ankle instability following a 3-day balance training program. *Athletic Training & Sports Health Care, 4*(4), 165-172.

Thomas, J.R., Nelson, J.K., & Silverman, S.J. (2011). *Research methods in physical activity.* Champaign, IL: Human Kinetics Publishers.

Thomas, J.R., Yan, J.H., & Stelmach, G.E. (2000). Movement substructures change as a function of practice in children and adults. *Journal of Experimental Child Psychology*, 75, 228-224.

Vance, J., Wulf, G., Töllner, T., McNevin, N., & Mercer, J. (2004). EMG activity as a function of the performer's focus of attention. *Journal of Motor Behavior*, *36*(4), 450–459.

Wattie, N., Schorer, J., & Baker, J. (2015). The relative age effect in sport: a developmental systems model. *Sports Medicine (Auckland, N.Z.)*, *45*(1), 83–94.

Willingham, D.B. (1998). A neuropsychological theory of motor skill learning. *Psychological Review*, 105, 558-584.

Wu, W., Porter, J., & Brown, L. (2012). Effect of attentional focus strategies on peak force and performance in the standing long jump. *The Journal of Strength & …*, *26*(5), 1226–1231.

Wulf, G. (2008). Attentional focus effects in balance acrobats. *Research Quarterly for Exercise and Sport*, *79*(3), 319–325.

Wulf, G. (2013). Attentional focus and motor learning: a review of 15 years. *International Review of Sport and Exercise Psychology*, *6*(1), 77–104.

Wulf, G., Chiviacowsky, S., Schiller, E., & Avila, L. T. G. (2010). Frequent external-focus feedback enhances motor learning. *Frontiers in Psychology*, *1*, 190.

Wulf, G., & Dufek, J. S. (2009). Increased jump height with an external focus due to enhanced lower extremity joint kinetics. *Journal of Motor Behavior*, *41*(5), 401–409.

Wulf, G., Dufek, J. S., Lozano, L., & Pettigrew, C. (2010). Increased jump height and reduced EMG activity with an external focus. *Human Movement Science*, *29*(3), 440–448.

Wulf, G., Höß, M., & Prinz, W. (1998). Instructions for motor learning: differential effects of internal versus external focus of attention. *Journal of Motor Behavior*, *30*(2), 169–79.

Wulf, G., Landers, M., Lewthwaite, R., & Töllner, T.(2009). External focus instructions reduce postural instability in individuals with Parkinson disease. *Physical Therapy, 89*, 162–168.

Wulf, G., Lauterbach, B., & Toole, T. (1999). The learning advantages of an external focus of attention in golf. *Research quarterly for exercise and sport*, *70*, 120–126.

Wulf, G., McConnel, N., Gärtner, M., & Schwarz, A. (2002). Enhancing the learning of sport skills through external-focus feedback. *Journal of Motor Behavior*, *34*(2), 171–82.

Wulf, G., McNevin, N. H., Fuchs, T., Ritter, F., & Toole, T. (2000). Attentional Focus in Complex Skill Learning. *Research Quarterly for Exercise and Sport*, *71*(3), 229–239.

Wulf, G., McNevin, N., & Shea, C. H. (2001). The automaticity of complex motor skill learning as a function of attentional focus. *The Quarterly Journal of Experimental Psychology*, *54A*, 1143–1154.

Wulf, G., Mercer, J., McNevin, N., & Guadagnoli, M. A. (2004). Reciprocal influences of attentional focus on postural and suprapostural task performance. *Journal of Motor Behavior*, *36*(2), 189–199.

Wulf, G., & Prinz, W. (2001). Directing attention to movement effects enhances learning: a review. *Psychonomic Bulletin & Review*, *8*(4), 648–60.

Wulf, G., Shea, C., & Park, J. H. (2001). Attention and motor performance: preferences for and advantages of an external focus. *Research Quarterly for Exercise and Sport*, *72*(4), 335–44.

Wulf, G., & Su, J. (2007). An External Focus of Attention Enhances Golf Shot Accuracy in Beginners and Experts. *Research Quarterly for Exercise and Sport*, *78*(4), 384–389.

Wulf, G., Töllner, T., & Shea, C. H. (2007). Attentional focus effects as a function of task difficulty. *Research Quarterly for Exercise and Sport*, *78*(3), 257–64.

Wulf, G., Zachry, T., Granados, C., & Dufek, J. S. (2007). Increases in Jump-and-Reach Height Through an External Focus of Attention. *International Journal of Sports Science and Coaching*, *2*(3), 275–284.

Zachry, T., Wulf, G., Mercer, J., & Bezodis, N. (2005). Increased movement accuracy and reduced EMG activity as the result of adopting an external focus of attention. *Brain Research Bulletin*, *67*(4), 304–309.

Zarghami, M., Saemi, E., & Fathi, I. (2012). External Focus of Attention Enhances Discus Throwing Performance. *Kinesiology*, *44*(1), 47–51.

Zentgraf, K., & Munzert, J. (2009). Effects of attentional-focus instructions on movement kinematics. *Psychology of Sport and Exercise*, *10*(5), 520–525.

Zimmermann, K. M., Bischoff, M., Lorey, B., Stark, R., Munzert, J., & Zentgraf, K. (2012). Neural correlates of switching attentional focus during finger movements: an fMRI study. Frontier in Psychology, 3, 1-11.

APPENDICES

Appendix I: Electronic Search Strategy: SPORTDiscus

1. Attentional focus
2. Focus of attention
3. Constrained action or constrained action hypothesis
4. 1 or 2 and learning effect
5. 1 or 2 and performance effect
6. 1 or 2 and learning advantage
7. 1 or 2 and performance advantage
8. External foc??
9. Internal foc??
10. 5 and 6
11. EFA
12. IFA
13. 1, 2 and 7, 8

Appendix II: Kappa Statistic Calculations

	Reviewer 2 Yes	Reviewer 2 No	Reviewer 2 Maybe	**Reviewer 2 Total**
Reviewer 1 Yes	*a*	*b*	*c*	$\mathbf{I_1}$
Reviewer 1 No	*d*	*e*	*f*	$\mathbf{E_1}$
Reviewer 1 Maybe	*g*	*h*	*i*	$\mathbf{U_1}$
Reviewer 1 Total	$\mathbf{I_2}$	$\mathbf{E_2}$	$\mathbf{U_2}$	**K**

$Kappa = \frac{Po-Pe}{1-Pe}$, where *Po* = observed accuracy = $\frac{a+e+i}{K}$ and where *a*, *e*, and *i* are the number of yes, no, and maybe studies reviewer 1 and reviewer 2 have in common; and K is total number of studies. *Pe* = expected accuracy =$\frac{(I_1*I_2)+(E_1*E_2)+(U_1*U_2)}{K^2}$, where I, E, and U are the total number of yes, no, and maybe studies selected by reviewer 1 and reviewer 2, respectively.

	Reviewer 2 (Shawn) Yes	Reviewer 2 (Shawn) No	Reviewer 2 (Shawn) Maybe	**Reviewer 2 (Shawn) Total**
Reviewer 1 (Ben) Yes	9	0	0	**9**
Reviewer 1 (Ben) No	1	66	11	**78**
Reviewer 1 (Ben) Maybe	1	7	15	**13**
Reviewer 1 Total	**11**	**73**	**16**	**100**

$Pe = \frac{(9*11)+(78*73)+(13*16)}{100^2} = \frac{(99)+(5694)+(208)}{10000} = \frac{6001}{10000} = 0.600$

$Po = \frac{(9)+(66)+(15)}{100} = Pe = \frac{90}{100} = 0.900$, $Kappa = \frac{(0.900-0.600)}{(1-0.600)} = \frac{0.3}{0.4} = \mathbf{0.75}$

Appendix III: Coding Form

STEP 1 CHOOSING APPROPRIATE PAPERS

This review is interested in any and all research that investigates the effect of differential attentional focus (i.e. internal and external) on sensorimotor task performance.

Each paper must provide the means and standard deviations for each of the performance measures so that comparisons on the basis of effect sizes can be calculated and compared with likewise papers. If reviewed papers do not have either, then primary authors shall be contacted in an attempt to obtain the required statistics.

STEP 2 SOURCES

Column 1: Study ID

Column 2: Report ID

Column 3: Citation and contact details: authors, date etc.

Column 2: Name of institution

Column 3: Is the Research (1) published or (0) unpublished?

Column 4: Source of Information - (2) peer-reviewed journal article? (1) Unpublished manuscript?

Column 5: If published, indicate name of journal

Column 6: If unpublished, (2) Ph.D dissertation? (1) Master’s thesis?

STEP 3 ELIGIBILITY

Column 8: Confirm Eligibility for Review: (1) Yes or (0) No

*Recall: This review is interested in any and all research that investigates the effect of differential attentional focus (i.e. internal **and** external) on sensorimotor task performance and learning*

Column 9: If *no*, then indicate reason for exclusion, **and cease data extraction**

STEP 4 PARTICIPANTS

Column 10: Input the total number of participants of the study

Column 11: Does the study have participants who have dropped out? (1) Yes or (0) No

Column 12: If *yes*, then indicate the number of participants accounting for attrition

Column 13: Indicate the recruitment protocol of participant; verbatim, if possible

Column 14: Were the participants randomly assigned to their respective focus groups/conditions? (1) Yes or (0) No

Column 15: <u>Status of participants</u> – are they compensated (e.g. paid, course credit) (2), no compensation (1) or not stated (0)?

Column 16: Were the participants unaware of the purposes and intentions of this experiment? (1) Yes or (0) No

<u>AGE</u>

Column 17: Indicate the age range of participants in the study

Column 18: Indicate the mean age of participants in the study

Column 19: Are the age cohorts explicitly stated? (1) Yes or (0) No

Column 20: If *yes*, then indicate the age cohort

Column 21: If *no*, then identify the applicable age cohorts based on mean age:

- (5) Late Childhood **(i.e. between 9-12 yrs)**
- (4) Adolescence **(i.e. between 13-18 yrs)**
- (3) Early Adulthood **(i.e. between 19-39 yrs)**
- (2) Middle Adulthood **(i.e. 40-59 yrs)**
- (1) Late Adulthood **(i.e. 60 + yrs)**

Column 22: Is there a comparison between age cohorts (e.g. children vs. adults)? (1) Yes or (0) No

Column 23: If *yes*, then identify the compared age cohorts (e.g. Children vs. young adults)

<u>SEX</u>

Column 24: Input total number of participants in terms of number of males

Column 25: Input total number of participants in terms of number of females

<u>HEALTH STATUS</u>

Column 26: Do the participants have an identified impairment that is (2) due to a disease, (1) due to aging, or (1) none at all (i.e. healthy)?

Column 27: Indicate their disease, if applicable

<u>SKILL LEVEL</u>

Column 28: Identification of participant's skill level

- (3) Experienced
- (2) Intermediate
- (1) Novice
- (0) Not stated

Column 29: How was the participants' skill level determined?

- (3) Quantitative measure (e.g. handicap in golf)
- (2) Investigator's determination via qualitative measure
- (1) Experimenter-determined experience (e.g. from how many years of playing/exposure, stating that the participant had no prior experience to the task)

Column 30: Quality of definition of the group (i.e. participant's skill level)?

- (2) Well defined (qualitative/quantitative measure)
- (1) Not enough information provided
- (0) not defined

Column 31: If well defined, indicate the qualitative/quantitative measure of assessing participants' skill level

STEP 5 METHODS

<u>TASK CHARACTERISTICS</u>

Column 32: Indicate the Task

Column 33: <u>Study design – participants</u> - Is the study a between-subjects (2) or within-subjects (1) design?

Column 34: <u>Study design – phases</u> - Does the study feature just an acquisition phase (3)? An acquisition and retention (2)? Or an acquisition, retention, and transfer (1) in the experimental design?

Columns 35 - 42: Indicate (if applicable) for each phase(s) of the experiment:

- Duration of trial in seconds of the trials (if applicable)
- Acquisition - Number of trials
- Acquisition - Number of blocks
- Number of days (for acquisition phase only)

- Retention - Number of trials
- Retention - Number of blocks
- Transfer - Number of trials
- Transfer - Number of blocks

Column 43: Task configuration of study - Does the study feature (2) two tasks (dual-task configuration) or a (1) single task that were/was performed?

Column 44: If dual-task, was the attentional focus on the (2) secondary or (1) primary task?

Column 45: Does the task have a recognizable beginning and end? (1) Yes or (0) No

Column 46: Was/were the task(s) performed in a (2) lab or in the (1) field?

Column 47: Was the task performed under a predictable environment (open and closed skilled task, respectively)? (1) Yes or (0) No

ENVIRONMENTAL CHARACTERISTICS

Column 48: Does the task utilize (2) full vision or (1) occluded vision?

Column 49: Does the participants have visual feedback augment them (2) during or (1) after task execution or (0) not at all?

Column 50: Is there a target associated with the task? (2) Yes or (1) No

Column 51: Is there a target, is it required for the participant to visually fixate on during task execution? (1) Yes or (0) No

Column 52: Does the task have the participant looking straight ahead? (1) Yes or (0) No

Column 53: The assumed visual system utilized throughout the task:

- (3) focal (i.e. a visual field < 15 degrees) or;
- (2) ambient (i.e. a visual field > 30 degrees) or;
- (1) ambiguous (i.e. both visual fields present utilized during execution) or;
- (0) not task related

STEP 6 INTERVENTIONS

Column 54: Did the experiment use randomization techniques to control for the following threats to internal validity?

- History and maturation (i.e. controlling for participant bias (what they bring before the intervention, and if their potential to condition to the intervention) — by **random placement or matched pairing of participants** into groups/conditions (i.e. counterbalancing)? (1) Yes or (0)
- Order effects and learning (i.e. assessing the practice condition (CI))—by **random ordering or presentation of the tasks**? (1) Yes or (0) No

Column 55: Indicate the instructional cues for external focus; verbatim, if possible

Column 56: Are the Attentional focus instructions to elicit external focus similar enough as per Wulf et al. (1998) (i.e. directing their attention to the effects of their movements of a particular aspect of a task) regarding the body movements? (1) Yes or (0) No

Column 57: Indicate the instructional cues for internal focus; verbatim, if possible

Column 58: Are the Attentional focus instructions to elicit internal focus similar enough as per Wulf et al. (1998) (i.e. directing their attention to the effects of their movements of a particular aspect of a task) regarding the effect of the movement? (1) Yes or (0) No

Column 59: Focus conditions/groups -- Does the study utilize comparison between just internal and external attentional focus groups (2) or does it include a control group (1)?

Column 60: Is the frequency of instructional cues explicitly stated? (1) Yes or (0) No

Column 61: If *yes*, indicate the frequency of instructional cues

Column 62: Were there any manipulation checks done regarding the assessment of instruction abidance of the participants?

Column 63: If *yes*, did they occur during (2) or after (1) intervention?

Column 64: If *yes*, indicate the manipulation checks

STEP 7 OUTCOMES

Column 65: Identify all independent variables used

Columns 66 - 69: Indicate F-statistics (i.e. main effects and interactions) from the data analysis

Columns 70 - 77: Indicate outcome measure(s) and its/their units of measurement

Columns 78 - 85: Indicate mean outcome measure score(s) and S.D. for internal focus group/condition

Column 86 – 93: Indicate mean outcome measure score(s) and S.D. for external focus group/condition

Columns 94 - 101: Is/Are the dependent measure(s) ratio (i.e. integer) (2) or interval (i.e. scale) (1) variables?

Columns 102 - 109: Is/are the dependent measures assessing task performance (2) or error (1)?

Columns 110 - 117: Direction of performance scores - If assessing performance scores are the (2) higher scores relatively better and lower score relatively worse or (1) vice versa?

Columns 118 - 123: Direction of error scores - If assessing error scores, are the (2) lower scores relatively better and higher score relatively worse or (1) vice versa?

STEP 8 RESULTS

Column 124: Is the effect size (i.e. represented as the standardized mean difference between external and internal foci) reported? (1) Yes or (0) No

Column 125: Is contact with the primary author required?

Column 126: If yes, why is contact required?

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